

**AN ECONOMETRIC ANALYSIS OF ZAMBIAN INDUSTRIAL  
ELECTRICITY DEMAND**

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## ABSTRACT

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The purpose of this thesis is twofold: to examine the electricity use in Zambia's mining industry by focusing on own-price, cross price and index of mining production elasticities of demand and on structural changes in demand patterns over the time period 1980-2008; and to expose any energy efficiency development in Zambia's mining industry. In this respected the study tested three hypotheses: (i) Electricity own-price changes have no significant impact on mining industrial electricity demand, (ii) diesel prices changes have no significant impact on mining industrial electricity demand; and (iii) there was no energy efficiency developments Zambia's mining industry during the period 1980-2008.

Data on three independent variables or predictors (average electricity prices, the diesel price and the index of mining production) and the independent variable (total annual electricity used by the mines) were collected from various databases (mainly from Zambia Central Statistics Office, U.S. Energy Information Administration, and the Zambia Energy Regulation Board). Also, interviews were conducted with respondents from four mines in Zambia (Lumwana Mine, Konkola Copper Mines, Kansanshi Mine, and Sino-Metals). Both statistical and non statistical methods were employed to analyse the data. The Statistical Package for Social Sciences (SPSS) was used to estimate the long-run mining industry electricity demand equation for Zambia.

The study finds long run electricity own price elasticity of -0.06; cross price elasticity of 0.031; and index of mining production elasticity of 0.154. The signs on all three elasticities are as predicted by theory. Both cross-price and index of mining production elasticities are found to be statistically significant at pre-selected regression alpha of 0.05. However, own price elasticity is statistically insignificant. The coefficient of determination of 0.518 entails that model is useful and the small p-value ( $0.000^a$ ) makes the model statistically significant. Whereas electricity own-price have insignificant long run impact on mining industrial electricity demand, diesel price have long run significant impact on mining industrial electricity demand.

The study also finds that there were minimal developments in the efficient use of electricity in the mining industry during the period 1980-2008. These included removal of import duty on energy efficient equipment; introduction of incentive pricing policies, load management programmes, electricity reduction programmes, information dissemination of demand-side

management, and changes in machinery or equipment by the mines in order to comply with Zambia environmental standards. The major barrier to energy efficient developments in mining industry during the period 1980-2008 seems to have been the absence of both national policy on energy efficiency and mine policy on energy efficiency.

## DEDICATION

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To the Almighty God

“For in him we live, and move, and have our being; as certain also of your own poets have said, “For we are also his offspring”.

To my “little angels”, Bupe Faith Namutula Chama, Yoram Chama (Junior), and Thabo Chama... the love, the phenomenon, and the splendor of my life!

And exclusively to my wife, Sibeso Likando Chama, without whose support I would not be at University of Oslo. She has been the one who most believed in me, many times more than myself. God brought us together.

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Any misunderstandings, misprints and mistakes in this thesis are certainly my liability alone.

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Chama Yoram Chama

Oslo, Norway – February 2012

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## **ABBREVIATIONS AND ACRONYMS**

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CSO	Central Statistics Office of Zambia
ERB	Zambia Energy Regulation Board
GDP	Gross Domestic Product
GRZ	Government of the Republic of Zambia
FNDP	Fifth National Development Plan
MOEWD	Zambia Ministry of Energy and Water Development
MOFNP	Zambia Ministry of Finance and National Planning
ZESCO	Zambia Electricity Supply Corporation Limited

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**1.1. INTRODUCTION**

This study focused on examining the electricity use in Zambia's mining industry by estimating the electricity demand function using historic data for the period 1980-2008, and exposing any energy efficiency development in the mining industry.

This introductory chapter is organised as follows: Section 1.2 presents the background to the study; Section 1.3 states the study purpose and hypothesis; Section 1.4 gives the significance of the study; and Section 1.5 presents the thesis outline.

**1.2. BACKGROUND TO THE STUDY**

Zambia, a landlocked country in Southern Africa, is bordered by the Democratic Republic of the Congo, Tanzania, Malawi, Mozambique, Zimbabwe, Botswana and Namibia, and Angola.

The mainstay of Zambia's economy is the mining industry, which is dominated by large copper mines. Currently, Zambia is Africa's largest copper producer, and its mining industry is still growing due to the favourable investment environment. China is the biggest investor in the mining industry in Zambia.

Significantly, Zambia's mining industry by its nature is electricity intensive and uses over 50 per cent of the national total annual electricity. Intensive use of electricity applies to both the extraction and processing of minerals because most on-and-off activities (such as smelting and leaching) and continuous activities (such as mine dewatering, lighting and ventilation) heavily depend on electricity. The major suppliers of electricity to the mining industry are the Zambia Electricity Supply Corporation Limited (ZESCO) and the Copperbelt Energy Corporation (CEC). However, each mine has standby diesel-driven generators for emergency supply of electricity.

In electricity demand in Zambia had been increasing and in 2006 the Government of the Republic of Zambia (GRZ) announced that the electricity demand growth was estimated at 100 MW per annum, and projected that the country would experience a power deficit by 2008. As predicted, the country started experiencing power deficits in 2008<sup>1</sup>. The deficits were blamed on the limited installed capacity, which was a mere 1786 MW in 2008. Zambia

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<sup>1</sup> Electricity deficit in Zambia is mainly a peak-time-use concept. The installed capacity is not sufficient during peak hour periods.

has, however, huge hydropower resource potential standing at an estimated 6,000 MW. The implication of the power deficits on Zambia as a nation was that several national goals such as accelerating economic growth, protecting the environment, reducing poverty, and achieving the Millennium Development Goals (MOFNP, 2006) might not be achieved.

The GRZ quickly responded to the power shortage problem by first, defining the national vision of electricity market in Zambia and second, commissioning several activities aimed at reducing power shortages. The national vision on electricity market was six-fold: (i) access to electricity by all customers; (ii) available electricity demand fully met; (iii) supply of reliable and quality electricity in an efficient manner; (iv) increased investment in electricity sector; (iv) protection of consumer interests; (v) ensuring cost reflective electricity tariffs; and (vi) demand-side management to improve efficient use.

Among the activities GRZ deemed necessary in the realization of the aforementioned vision was to increase research and development. Specifically, GRZ in 2006 documented that research and development in the energy sector would be a priority during the “Fifth National Development Plan” period 2006-2010 (MOFNP, 2006). This high profile declaration signified the necessity of econometric studies on electricity market in informing GRZ interventions. Lorde et al. (2010) illuminates that econometric analysis of the relationship between energy consumption by industries is rarely conducted for purely empirical interest, but mainly for significant policy implications. For example, an econometric study by Akinlo (2008) on Energy consumption and economic growth: Evidence from 11 Sub-Sahara African countries, concludes that “each country should formulate appropriate energy conservation policies taking into cognizance of her peculiar condition”.

That research and development in the energy sector would be a priority during the Fifth National Development Plan was not a mere symbolic statement by GRZ. A landmark study to inform GRZ on “ensuring cost reflective electricity tariffs” was completed in 2007 by IPA Energy Consulting. However, this study focused solely on the supply side of the electricity market and neglected the demand-side. In short, the study did not consider how electricity demand would be affected by the increasing electricity prices to make them cost reflective.

Econometric studies on demand-side of electricity market are important in informing government policy on pricing. For instance, member countries of the Southern African Power Pool (SAPP) have conducted econometric studies on electricity-demand. For example, the number of econometric studies on electricity demand in South Africa has increased in recent years. The recent studies include: “Aggregate demand for electricity in South Africa: An analysis using the bounds testing approach to cointegration” (Amusa et al., 2009);

“Electricity consumption and economic growth in South Africa: A trivariate causality test” (Odhiambo, 2009); Aggregate electricity demand in South Africa: Conditional forecasts to 2030 (Inglesi, 2010); “The evolution of price elasticity of electricity demand in South Africa: A Kalman filter application” (Inglesi, 2011); and “South Africa’s electricity consumption: A sectoral decomposition analysis” (Inglesi-Lotz and Blignaut, 2011). These studies have not only informed the pricing policies in South Africa, but have also challenged the bases for increasing the electricity prices in South Africa. Amusa et al. (2009), for instance, found electricity prices having an insignificant effect on aggregate electricity demand, and they stressed that future pricing policies in South Africa must ensure that electricity prices are cost reflective and enhance efficiency of electricity supply and use.

In addition, several studies outside Africa have analysed exogenous and endogenous drivers for efficient use of electricity in industries. Exogenous factors include the price of electricity the amount of electricity available; national energy efficiency policies and laws; research and development; international trade (transfer of technologies). The endogenous drivers include effective energy efficient policies and strategies of a firm; organisational culture; energy management systems; energy efficiency investment - for example, changes in machinery, equipment and technology; changes in machinery and equipment; training activities; voluntary audit; major product/process related technological changes, whether or not introduced as part of public/private national and the R&D programmes; optimization of production capacity and production level; conversion of industrial business - in terms of both products and processes (Gillingham et al 2009; Martinez 2009; World Energy Council 2010).

As well, there is rich literature on the ‘benefits of the efficient use of electricity in industries (see, for example, Morvaj and Bukarica 2010; Baumgartner and Muggli 1996; Howland and Murrow 2009; World Energy Council 2010). Indeed, GRZ is equally aware about the many benefits of the efficient use of electricity.

However, having a good vision of electricity market is not good enough if a vision is not implemented. The GRZ declaration of increased research on energy sector has been one sided. The electricity supply-side has been studied and the demand side neglected. Additionally, the activities initiated by GRZ and ZESCO to improve efficient use of electricity in industries are reported not to have been fully utilised by industries. An amplification of these two issues seems significant.

First, the prominent electricity supply-side study called the “Cost of Service Study”, was conducted during the period 2006-2007 by IPA Energy Consulting (UK-based firm). The

study was a major component of the Project sponsored by the World Bank and Swedish International Development Agency (SIDA) to strengthen the capacity of the Energy Regulation Board (ERB). Specifically, the study aimed at helping both ZESCO and ERB to develop a deeper understanding of ZESCO's cost structure, cost drivers, and its revenue requirements that need to be reflected in appropriate tariff levels so that ZESCO could meet the Government's commercialization objectives and therefore its supply obligations in the future (IPA Energy Consulting, 2007). Based on the outcomes of "Cost of Service Study" and in the presence of a widespread consensus among various stakeholders on the need for ERB to reject ZESCO's application for upward adjustment of electricity tariff rates by 66 per cent, electricity tariffs were adjusted upwards in 2008.

There is no proof of any studies that were conducted before and after adjustment of electricity tariff rates to estimate the effects of price adjustments on electricity demand by industry, residential or commercial consumers of electricity. GRZ should cherish a timely recommendation by European Union of the Electricity Industry [EURELECTRIC] (2011) that policy makers should exercise care to avoid imposing higher costs on customers that can dampen economic growth.

Second, I have already indicated the activities initiated by GRZ and ZESCO to improve efficient use of electricity in industries are reported not to have been fully utilised by industries. Sisala (2008), former director for ZESCO, exposed that Zambia can save up to 145MW a year just from the use of energy efficient bulbs by consumers. Sisala goes on to explain that ZESCO, at utility level, had implemented following energy management activities: (i) free of charge energy audits to consumers and (ii) Time of Use (TOU) tariff for Maximum Demand (MD) consumers. All electricity consumed during the off-peak time period was subjected to a 25 per cent discount on energy charges and a 50 per cent discount on capacity charges. All electricity consumed during the peak time period attracts a surcharge of 25 per cent penalty on both energy and capacity charges. To the contrary, Sisala concludes that industries made low use of two service introduced by ZESCO. In addition, Zambia cannot point to any study that exposes any developments in the efficient use of electricity in the mining industry.

Significantly, lack of econometric studies of Zambia's industrial electricity demand and non-exposure of any energy efficiency development in the Zambian industry is a serious omission. It is serious particularly when put into consideration that econometric analyses of industrial electricity demand and the exposure of any energy efficiency development in the Zambian industry are not merely issues of empirical interest, but issues that have significant policy



implications, and significant bearing the growth of the Zambian economy. If these issues are not dealt with the seriousness they deserve, opportunities that would have otherwise been available for making electricity in Zambia become an engine for development will become foreclosed. This in the long run will make it difficult for Zambia to sustain continued economic development.

In the light of foregoing background, the urgent need for econometric studies of electricity demand and its efficient use in the mines in Zambia can not be overemphasised. This study, though primarily academic, is a springboard for such studies on Zambia. On this note, I will state the purpose and the hypotheses of this study in the next section.

### **1.3. STUDY PURPOSE AND HYPOTHESES**

#### ***1.3.1. Study purpose***

The study purpose is twofold: to examine the electricity use in Zambia's mining industry by focusing on own-price, cross price and index of mining production elasticities of electricity demand and on structural changes in demand patterns over the time period 1980-2008; and to expose any energy efficiency development in Zambia's mining industry.

The study focuses on the mining as opposed to both "mining and manufacturing" sectors because the mining industry is the biggest consumer of electricity in Zambia. This is rightly stated by the Zambia Energy Regulation Board (ERB) as follows:

The Mining sector continues to rank as the biggest consumer of power taking up about 54.5% of total consumption. This is followed by the Services sector which includes Residential consumers at 27.5%, followed by Manufacturing (6.6%) and Finance and Property (3.5%); Energy and Water (1%); Construction (0.09%) and Transport (0.2%) (ERB 2009: 7).

#### ***1.3.2. Study hypothesis***

Based on the aforementioned study purpose and the literature review presented in Chapter 4, this study tested the following hypotheses using data on mining in Zambia.

### ***Hypothesis A:***

- *H<sub>0</sub>: Electricity own-price changes have no significant impact on mining industrial electricity demand.*
- *H<sub>1</sub>: Electricity own-price changes have significant impact on mining industrial electricity demand*

If a regression result is significant in electricity price variable then the null hypothesis will be rejected. This will indicate that electricity price changes have an impact on the industrial electricity demand.

### ***Hypothesis B:***

- *H<sub>0</sub>: Diesel prices changes have no significant impact on mining industrial electricity demand.*
- *H<sub>1</sub>: Diesel prices changes have significant impact on mining industrial electricity demand.*

If a regression result is significant in petroleum price variable then the null hypothesis will be rejected. This will indicate that petroleum price changes have an impact on the industrial electricity demand.

### ***Hypothesis C:***

- *H<sub>0</sub>: There was no energy efficiency developments Zambia's mining industry during the period 1980-2008.*
- *H<sub>1</sub>: There was energy efficiency developments Zambia's mining industry during the period 1980-2008.*

Both statistical and non-statistical data will be used to validate Hypothesis C.

## **1.4. SIGNIFICANCE OF THE STUDY**

This study is neither perfect nor complete in the sense that there may be many issues on industrial electricity demand and efficient use of electricity not included here. To the best of my effort, however, what I have put into this study constitutes the most essential parts of the manifestations of the industrial electricity use, in particular, mining industry. This study contributes to the body of scholarly knowledge by estimating the industrial electricity demand efficient use of electricity in Zambia. The study extends our theoretical, methodological, and empirical understanding of the dynamics of industrial electricity demand and efficient use of

electricity, topics not previously addressed on Zambia. Optimistically, being the first of its kind on Zambia, this study provides a basis for further study and exploration as well as stimulates better understanding of the industrial electricity demand and efficient use of electricity in industries.

## **1.5. THESIS OUTLINE**

This introductory chapter has covered the background to the study; the study purpose and hypothesis; and the significance of the study. The remaining six chapters are organized as follows. Chapter 2 discusses Zambia's electricity sector and Chapter 3 covers Zambia's industry sector. Chapter 4 presents the literature review. Chapter 5 (methodology) presents the theory of demand; a theoretical model; econometric model, and data set description. Chapter 6 presents and discusses empirical results. Finally, chapter 7 presents a summary of the key findings; highlights the important policy implications; highpoints the study limitations; and suggests the future extension of the study.

## **1.6. CHAPTER SUMMARY**

In this chapter, I have demonstrated that although GRZ places a premium on increased research and development in addressing inefficiency problems in the electricity market, yet the demand side of electricity market in terms industrial electricity demand and efficient use of electricity in industries in Zambia have not been researched. One prominent study on the electricity supply-side was conducted between 1980 and 2008 to justify the need to increase electricity tariffs in Zambia so that they become cost reflective.

In this light, this study aims at examining the electricity use in Zambia's mining industry by focusing on price and output elasticities of electricity demand and on structural changes in demand patterns over the time period 1990-2008; and to expose any energy efficiency development in Zambia's mining industry. Three hypotheses have been developed: (i) the electricity own-price changes have no significant impact on mining industrial electricity demand; (ii) the prices of diesel (the expected substitute of electricity) have no significant impact on mining industrial electricity demand; and that (iii) there were no energy efficiency developments Zambia's mining industry during the period 1980-2008.

Being the first of its kind, this study on econometric analysis of Zambia's mining industry electricity use and developments in electricity efficiency both academically and practically significant. On this note, I will present Zambia's electricity market in the next chapter.

### **2.1 INTRODUCTION**

In the previous chapter I covered the background to the study; the study purpose and hypotheses; the significance of the study; and the thesis outline. In this chapter I will describe Zambia’s electricity market. I will proceed as follows: Section 2.2 outlines the national policy and legislation; Section 2.3 highlights the energy subsectors in Zambia; Section 2.4 states the electricity suppliers in Zambia; Section 2.5 discusses the electricity demand in Zambia; Section 2.6 states the challenges in the electricity marketing in Zambia; and Section 2.7 gives the chapter summary.

### **2.2 NATIONAL POLICY AND LEGISLATION**

#### ***2.2.1 The Ministry of Energy and Water Development***

The Zambian Ministry of Energy and Water Development (MOEWD), comprising two Departments (Energy and Water departments), is responsible for the formulation and implementation of policy in the energy sector. MOEWD has several objectives to Achieve: articulate and implement Policy on Energy; formulate programs for the development of the Energy sector; ensure that there are efficient and reliable supplies of energy for socio-economic development; integrate the Energy sector into the national and regional development strategies; and regulate the Energy sector through appropriate legislation including the development of new laws and bye-laws (MOEWD 2011).

#### ***2.2.2 National Energy Policy***

In 1994 Zambia adopted the National Energy Policy (NEP) with a twofold aim: (i) to strengthen the management and coordination of energy sector activities at national level, and (ii) to advance the efficiency and effectiveness of service delivery by the boards and utilities in the energy sector and institutional level. Consequently, appropriate pieces of legislation in the form of the Energy Regulation Act, Rural Electrification Act and amended Electricity Act have been enacted. These pieces of legislation have led to the formation of the Energy Regulation Board and the Rural Electrification Authority.

### ***2.2.3 National development plans***

The Fifth National Development Plan – (FNDP 2006-2010) and Sixth National Development Plan (SNDP 2011-2015) have provided national strategic direction of the energy sector in Zambia. During the FNDP period, the vision and goal concerning the energy sector were stated as follows:

The vision is: Universal access to clean, reliable and affordable energy at the lowest total economic, financial, social and environmental cost consistent with national development goals by 2030.

The goal is: To ensure availability and accessibility to adequate and reliable supply of energy from various sources at the lowest total economic, social and environmental cost consistent with national development goals of sustained growth, employment generation and poverty reduction (MOFNP 2006: 134).

During the SNDP the vision for the energy sector mentioned in the FNDP remained unchanged. However, the goal was quantified: (i) An increase of at least 1,000 Mw (50 per cent) to the 2010 electricity generation capacity of 1,900 Mw; (ii) An increase of rural access to electricity from 3.5 per cent to at least 15 per cent and national access from 22 per cent to 40 per cent; and (iii) An increase of over 100 per cent in the existing petroleum bulk storage facilities in order to achieve 30 days petroleum strategic stock.

### ***2.2.4 The Energy Regulation Board of Zambia***

The ERB is a legal entity established under the Energy Regulation Act of 1995, Chapter 436 of the Laws of Zambia. The role of the ERB is that of balancing the needs of undertakings with the needs of energy consumers. The Board has the responsibility to ensure that utilities earn a reasonable rate of return on their investments that is necessary to provide a quality service at affordable prices to the consumer. In order to carry out this role, the ERB, among other functions, ensures that all energy utilities in the sector are licensed, monitors levels and structures of competition, investigates and remedies consumer complaints.

### ***2.2.5 The Rural Electrification Authority of Zambia***

The REA is a legal entity established under the Rural Electrification Act of 2003 of the Laws of Zambia, whose summary is stated as follows:

An Act to establish the Rural Electrification Authority and to define its functions; to establish the Rural Electrification Fund; and to provide for matters connected with or incidental to the foregoing.

### **2.2.6 Other legislations**

In addition to Energy Regulation Act of 1995 and Rural Electrification Act of 2003, Zambia has Electricity of 1995, Electricity (Amendment) Act of 2003, and Petroleum Act of 1930.

The *Electricity Act of 1995* empowers ERB to regulate the generation, transmission, distribution and supply of electricity. The empowerment of ERB by the Electricity Act can be demonstrated by quoting Section 3 which reads as follows:

Subject of subsection (2) and the Energy Regulation Act, no person shall establish or carry on any undertaking unless in accordance with this Act and the Energy Regulation Act.

The *Electricity (Amendment) Act of 2003* addresses the shortcomings of the Principal Electricity Act of 1995. The *Petroleum Act of 1930* makes the provision for regulating the importation, conveyance and storage of petroleum and other inflammable oils and liquids. The ERB regulates petroleum in Zambia.

### **2.2.7 Effectiveness of the Ministry of Energy and Water Development**

Among the many functions of MOEWD is to integrate the Energy sector into the national and regional development strategies. To the contrary, various sector development plans contained in both the Zambia's Fifth and sixth National Development plans have not addressed energy requirements. In addition, MOEWD (2010) admitted having done very little in steering energy management efforts in the country:

Energy Management refers to the control and use of energy efficiently in industry and domestic applications aimed at reducing energy consumption without sacrificing productivity or increasing costs. At present, very little is being done in the area of energy management (MOEWD 2010).

All things being constant, it is proper to speculate that either MOEWD has a weak infrastructural power in providing economic agents with incentives to engage in energy efficiency activities, or the Government simply makes symbolic policies (Jansen 2001) partly because the Zambia Constitution, according to Hansungule (2007), render any national policy

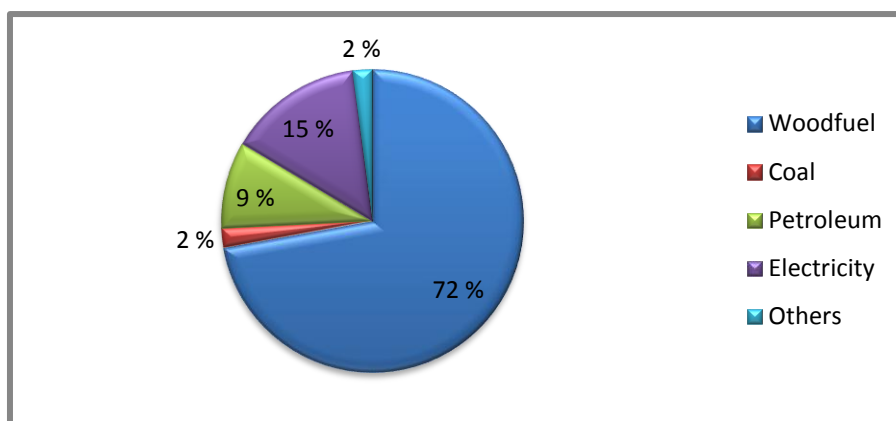
a mere document with no legal back-up. Referring to the Fifth National Development Plan document, a Zambia based professor, Hansungule states as follows:

FNDP is not a legally binding covenant even if it is tempting to perceive it as such between the rulers and the ruled. This is why it can use or its drafters can afford to use the loftiest of terms because legalistically speaking, there is no fear they will be legally held accountable to it. There is no intention on the part of the government to open itself to legal suits based on promises in the Plan (Hansungule 2007: 5).

## 2.3 ZAMBIA'S ENERGY SUBSECTORS

Zambia's energy sector comprises seven subsectors: electricity; wood fuel; petroleum, coal; renewable energy; and other-forms-of-energy. Figure 1 summarises the energy contribution of each subsector in 2006.

*Figure 1: Zambia's energy consumption by subsector in 2006*



Sources: Author's compilation from information contained in FNDP (MOFNP 2006).

### 2.3.1 Wood fuel sub-sector

The significant features of wood fuel sector in Zambia are that it contributes at least 3.7 per cent to GDP; provides energy for the agricultural and domestic needs of 90 per cent of the Zambian population; and is responsible for annual deforestation is estimated at 900,000 hectares (MOFNP 2006: 97).

### **2.3.2 Coal**

On coal the highlights GRZ explains as follows:

Proven coal deposits are estimated to be over 30 million tons. Probable coal reserves at Luangwa North, Luano, Lukusashi in the Luangwa Valley and Kahare, Chunga, Lubaba in the Western trough system are believed to be in the region of several hundred million tons though more exploration work is required to ascertain the exact nature and extent of the deposits. Currently Zambia has two coalmines. The major one [Maamba Collieries] was once government owned and has a capacity of 1 million tons per year. However, despite the large reserves, the contribution of coal to total energy has been declining over the years due to the lack of capitalization in the industry that resulted in production constraints at the main mine and also the reduced demand in the mining industry (MOEWD, 2010).

Despite the acknowledgement of the problems associated with coal mining, the Government have did not state any envisaged solutions during the Fifth National Development Plan period

### **2.3.3 Petroleum**

Zambia has no known oil or gas reserves and therefore no upstream oil industry. It imports all its petroleum requirements, which contribute 9% to the national energy demand. Petroleum is a key input in the Mining and Transport sectors. Zambia's conventional infrastructure for petroleum import and processing include the 1,706-kilometre pipeline which runs from Dar-es-Salaam in Tanzania to Ndola, a Petroleum Refinery with a design capacity of 800, 000 tons per annum and the Ndola Fuel Terminal (MOEWD 2010).

### **2.3.4 Renewable energy**

The renewable energy sources in Zambia, as stated by MOEWD (2010), are increasingly being used but still remain insignificant in terms of contribution to the total national energy supply. The Renewable energy sources in Zambia include the following: solar (thermal and photovoltaic); mini/microhydro; biomass (agricultural wastes, forestry waste, industrial/municipal organic wastes, energy crops and products and animal waste); geothermal, and wind. These sources have great potential for electricity production and use in the transport sector.



### 2.3.5 Nuclear energy

Although Zambia has uranium deposits, yet the nuclear energy is not developed. However, interest in Zambian uranium has been growing for a number of years. The Government has in fact passed a law allowing foreign companies to exploit uranium on a large scale, with the aim of diversifying its mining sector, which is too heavily dependent on copper, and so enhancing economic development.

## 2.4 ELECTRICITY SUPPLIERS

In Zambia, the year 2008 saw the number of electricity companies increase to five from the four already existing ones: Zambia Electricity Supply Corporation Limited (ZESCO), Copperbelt Energy Corporation Plc (CEC), Lunsemfwa Hydro Power Company (LHPC) and Zengamina Hydro Power Company (ZHPC). North-western Energy Company Ltd (NEC) situated in North-western Province, was the new company which began operations in 2008.

### 2.4.1 Zambia Electricity Supply Corporation Limited

ZESCO, a parastatal company established in 1970, with an arms-length relationship with GRZ, manages electricity supply in Zambia under the Performance Contract that was signed between GRZ and ZESCO in 1996. The contract defines the commercialization issues and other operational benchmarks for ZESCO over the contract period of three (3) renewable years.

As a vertically integrated public utility, ZESCO is involved in generation, transmission, distribution and supply of electricity. It has assets in excess of US\$3.0 billion and a customer base of over 300,000. The generation assets of ZESCO in 2008 are shown in Table 1.

**Table 1: ZESCO Generation assets and capacity 1980- 2008**

ZESCO ASSET	GENERATION CAPACITY (2008)
Kafue Gorge	900MW (990MW)
Kariba North Bank	600MW (720MW)
Victoria Falls	108MW
Small Hydros	24MW
<b>TOTAL INSTALLED CAPACITY</b>	<b>1,640MW</b>

Source: ERB 2009

ZESCO annual turnover in 2008 was US\$300million and had a total of 3,900 employees with a customer/employee ratio of 80. In the same year, ZESCO sold about 9,450GWh, of which 50 per cent was sold to Copperbelt Energy Corporation (CEC) and other mining customers and five per cent exports to regional markets.

#### ***2.4.2 Copperbelt Energy Company***

CEC is a privately owned corporation involved in the transmission and distribution of electricity to the Mines. CEC owns 80MW Gas Turbines located on the Copperbelt Province of Zambia. In addition, CEC has BSA with ZESCO to Purchase Power and Sell to Copperbelt Mines (Ex-ZCCM). CEC continued to be the major supplier of power to the mines on the Copperbelt province.

During 2008, CEC Plc. reduced power supply to the mines by 16 per cent of their normal demand of 530MW because of generation shortfall by ZESCO. Towards the end of the year the reductions were also attributed to the scaling down of mining activities at Luanshya Copper Mines (LCM) and Chambeshi Metals which were placed under care and maintenance.

CEC in partnership with Swiss mining giant Glencore International AG had expressed interest to develop Kafue Gorge Lower at a cost of US\$1.5 billion. CEC also wheels about 2,709MW on behalf of ZESCO's Copperbelt loads as well as 210MW in respect of SNEL exports to SAPP. In 2008, CEC's demand was projected to increase to about 750 – 800 MW by 2010 (ERB 2009).

#### ***2.4.3 Lunsemfwa Hydro Power Company:***

Lunsemfwa Hydro Power Company is the only independent power producer in the electricity industry connected to the ZESCO transmission system. It has only two customers: ZESCO Ltd and Chimani Manganese mine of Kabwe. In 2008, generation sent out from the two power stations was recorded at 309,035MWh for energy while capacity was recorded at 437,792 kVA. Total sales to ZESCO were 287,385 MWh in energy and 436,851Kw in capacity (ERB 2009).

#### ***2.4.4 Zengamina Mini-Hydro Power Company***

Zengamina Hydro Power Company, a new mini hydro station situated in North-Western province of Zambia, has a network of about 35 km of high voltage and 10 km of low voltage

lines. Its customers include Kalene Mission Hospital, traditional chiefs' palaces, schools and clinics were prioritized for connection to the mini hydro grid and Ikelenge Township Electricity Demand in Zambia (ERB 2009).

#### ***2.4.5 Northwestern Energy Corporation Ltd***

Northwestern Energy Corporation Ltd (NEC) was licenced by the ERB in 2008 to distribute and supply electricity to residential, commercial and light industrial customers at Lumwana in the Northwestern Province of Zambia. NEC and ZESCO entered into a fifteen (15) years Bulk Supply Agreement (BSA) for the maximum demand supply of 2MVA. ZESCO began energy supplies to NEC in October 2008 with aggregate sales of 1,050 MWh up to the end of the year 2008 (ERB 2009).

## **2.5 ELECTRICITY DEMAND**

### ***2.5.1 Annual national maximum demand***

The electricity access rates at national level in 2008 was 22 per cent which translated to 49.3 per cent in urban areas and only 3.2 per cent in rural areas for a population of 12 million people (ERB 2009: 4). In spite of the low access rate of electricity, total electricity demand in Zambia has been increasing. This is evidenced by Table 2 which shows the electricity demand for member countries of Southern Africa Development Corporation (SADC) for the period 1998 – 2012.

According to Table 2, Zambia is the third largest consumer of electricity in the SADC region. Whilst the annual electricity maximum demand for Zambia was 1,126MW of in 1998, the anticipated demand stands at 1606MW in 2012, registering an increase of 480MW (42.6 per cent).

**Table 2: Annual national electricity maximum demand in MW in the SADC Region**

HISTORIC									FORECAST						
YEAR	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Angola	209	326	250	291	330	342	374	397	846	871	898	924	952	981	1010
Botswana	239	256	285	337	362	393	402	434	452	479	507	534	562	591	609
DRC	830	841	895	929	991	994	1012	1012	1,070	1,100	1,138	1,172	1,207	1,244	1281
Lesotho	69	77	85	88	89	90	90	90	115	125	130	136	142	148	152
Malawi	190	185	205	212	236	261	227	242	311	330	350	371	394	414	426
Mozambique	245	214	231	234	250	258	266	285	305	326	349	374	400	428	441
Namibia	292	314	320	335	362	371	393	491	670	681	692	703	713	724	746
South Africa	27,803	27,813	29,188	30,599	31,621	30,154	34,195	33,461	35,100	36,200	37,032	38,144	39,288	40,467	41,681
Swaziland	145	153	154	159	160	172	171,5	172	185	191	196	202	208	215	221
Tanzania	368	394	426	465	474	506	509	531	654	700	747	786	873	910	937
Zambia	1,126	1,069	1,085	1,087	1,118	1,255	1,294	1,330	1,374	1,399	1,426	1,499	1,529	1,560	1606
Zimbabwe	1,950	2,034	1,986	2,013	2,028	2,007	2,069	2,066	2,208	2,287	2,363	2,446	2,527	2,610	2688
Total Interconnected	32,699	32,771	34,229	35,781	36,981	35,694	39,893	39,341	41,479	42,788	43,832	45,209	46,576	47,986	49,426
Total SAPP	33,466	33,676	35,110	36,749	38,021	36,803	41,003	40,511	43,290	44,689	45,827	47,290	48,795	50,291	51,800

Sources: SAPP Statistics 2005/2006

### 2.5.2 Electricity consumption by sector

As already stated in Chapter 1 the mining sector has been ranking as the largest consumer of electricity in Zambia for decades. Table 3 summarizes the electricity consumption by sector in 2008.

**Table 3: Electricity consumption by sector in 2008**

Economic sector	Average No. of active customers	Units consumed kWh	% contribution to Total
Mining	75	4,005,429,938	54.5%
Services & Residential	277,043	2,021,850,057	27.5%
Manufacturing	1,411	482,773,751	6.6%
Finance & Property	4,648	259,375,721	3.5%
Agriculture	1,294	166,421,022	2.3%
Trade	9,249	159,383,030	2.2%
Other	5,693	165,126,771	2.2%
Energy & Water	264	72,180,352	1%
Transport	273	18,024,028	0.2%
Construction	89	6,531,171	0.09%
<b>Total</b>	<b>300,039</b>	<b>7,357,095,841</b>	<b>100%</b>

Source: ERB 2008

### 2.5.3 The main drivers of electricity demand and deficit in Zambia

In his presentation on “Challenges and Possible Solutions in the Power Sector” to the Economics Association of Zambia on 10<sup>th</sup> July 2008, the former ZESCO Managing Director, Sisala, states drivers of electricity demand and deficit in Zambia: (i) economic Growth of more than 5 per cent in most of the SADC member countries resulting in unprecedented growth in electricity consumption and demand (see Table 6) ; (ii) increased demand for base metals resulting in high metals prices on world market; (iii) established of new and expansion of existing mining companies; (iv) growth in other sectors such as industry, commerce, agriculture and housing; (v) country electrification programs – rural and urban; and (vi) inadequate investment in generation and transmission infrastructure over the last 20 – 30 years.

Table 4 shows that 2007 peak demand of 1,468MW in Zambia was above the available capacity in 2008.

**Table 4: Installed Versus peak demand electricity capacity in SAPP**

SAPP DEMAND AND SUPPLY SITUATION					
No.	Country	Utility	Installed Capacity [MW]	Available Capacity [MW] As at Feb 2008	2007 Peak Demand [MW]
1	Angola	ENE	1,155	870	535
2	Botswana	BPC	132	90	496
3	DRC	SNEL	2,442	1,170	1,075
4	Lesotho	LEC	72	70	109
5	Malawi	ESCOM	305	246	240
6	Mozambique	EDM	248.5	173.8	365
		HCB	2,250	2,075	
7	Namibia	NamPower	393	360	449
8	South Africa	Eskom	43,061	38,384	36,513
9	Swaziland	SEB	51	50	196
10	Tanzania	TANESCO	897	680	653
11	Zambia	ZESCO	1,632	1,200	1,468
12	Zimbabwe	ZESA	2,045	1,125	1,758
TOTAL SAPP			54,684	46,494	43,857
Total Interconnected SAPP			52,327	44,698	42,429

Source: SAPP Statistics ([http://www.sapp.co.zw/docs/Statistics%20Annual%20Report\\_2008.pdf](http://www.sapp.co.zw/docs/Statistics%20Annual%20Report_2008.pdf))

## **2.5.4 Electricity tariffs in Zambia**

### **2.5.4.1 The role of tariffs**

The ERB Head Engineer, James Manda (2010) explains that the role of tariffs in Zambia is fourfold: (i) to inform customers about costs for new use of electricity; (ii) to contribute to the optimal use of existing facilities; (iii) to cover the costs of the electric power companies; and (iv) to create balance between supply and demand of electricity.

### **2.5.4.2 Three major types of electricity tariffs in Zambia**

These are: Bulk supply tariffs, Export tariffs and Retail Tariffs. Bulk supply tariffs apply to large scale customers such as the Copperbelt Energy Corporation. The export tariffs, as the name suggests, apply to electricity sold outside Zambia. Both bulk supply and export tariffs are negotiated between supplier and buyer and are typically governed by long-term contracts. The retail tariffs are further categorized into *Residential Tariffs* (metered and unmetered households), *Commercial Tariffs*, *Social Services Tariffs* (such as tariffs for hospitals), and *Maximum Demand Tariffs* (mainly targeted at industrial and mining sector).

In addition to the above types of tariffs, Zambia, in July 2002, introduced *Farmers tariffs*, special tariffs aimed at encouraging primarily crop production through irrigation.

### **2.5.4.3 Cost effectiveness of electricity tariffs in Zambia**

That electricity tariffs in Zambia are not cost effective is indisputable when one studies the 2007 report on “Cost of Service Study” on commercialization of ZESCO. The study was conducted by IPA Energy Consulting, a Scottish company, over a time period of 12 months in collaboration with ZESCO and the ERB. This study was a major component of the Project sponsored by the World Bank and Swedish International Development Agency (SIDA) to strengthen the capacity of the ERB. One of the findings of the study is that ZESCO underprices the mining load. IPA (2007: 8) reports as follows:

As the Cost of Service Study progressed, we also became aware of the problem of under pricing the mining load, which currently represents 50% of total consumption in Zambia.

Not only is the existing CEC contract under priced relative to the Cost of Service, but so are the new contracts ZESCO is entering into with new retail mining loads. In fact, it appears that ZESCO is selling to new retail mining loads at prices lower than its wholesale price to CEC. This raises the question as to whether ZESCO is engaging in an

anti-competitive practice by intentionally selling at retail lower than it sells at wholesale in order to undercut CEC.

The negative implications of this problem are rightly stated by IPA Energy Consulting (2007: 9): (i) GRZ as ZESCO's shareholder may be required to contribute this US\$ 926 million to keep ZESCO whole if the under pricing is allowed to continue; (ii) alternatively, tariffs for the residential customer group would have to pay about 30 per cent more than their fair share of Revenue Requirements in order to continue this subsidy to the mines; (The Residential customer group is the only one with enough consumption over which the burden of this cross subsidy could feasibly be spread.); and (iii) the physical system will continue to degrade for lack of funding, and load shedding would likely increase substantially because the mines take priority service on a 24/7 basis (IPA 2007: 10).

At region level, Zambia has the lowest electricity tariffs among 14 Africa countries most of which are members of Southern African Power Pool (SAPP). Table 5 shows the comparison of electricity tariffs within the 14 Africa countries.

**Table 5: Electricity tariffs for SAPP countries in 2007**

UTILITY	COUNTRY	CURRENCY	DOMESTIC (kWh)	COMMERCIAL (kWh)	INDUSTRIAL (kWh)
BPC	BOTSWANA	USCents/kWh)	6.2	6.1	4.2
CEB	MAURITIUS	USCents/kWh)	12	18.9	7.2
EDM	MOZAMBIQUE	USCents/kWh)	11	1.4	5.3
ENE	ANGOLA	USCents/kWh)	3.7	3.9	2.2
ESCOM	MALAWI	USCents/kWh)	3.6	6.3	3.9
Eskom	SOUTH AFRICA	USCents/kWh)	6.1	6.0	2.2
KPLC	KENYA	USCents/kWh)	9.4	11.4	8.3
LEC	LESOTHO	USCents/kWh)	6.9	9.6	4.3
NamPower	NAMIBIA	USCents/kWh)	10.8	10.2	7.0
SEB	SWAZILAND	USCents/kWh)	6.9	8.4	5.0
TANESCO	TANZANIA	USCents/kWh)	7.5	8.2	6.3
UMEME	UGANDA	USCents/kWh)	23	22.6	10.9
ZESA	ZIMBABWE	USCents/kWh)	0.7	0.5	0.3
ZESCO	ZAMBIA	USCents/kWh)	2.5	3.7	2.6
REG. AVERAGE	SADELEC	USCents/kWh)	6.4	8.4	5.0

Source: Sisala (2008)

It is clear from Table 5 that apart from Zimbabwe and Angola, Zambia had the lowest electricity tariffs in 2007.

Amidst these low tariffs, it is hard to reflect if ZESCO would be able to raise or support new investment for system expansion if the mining contracts and agreements cannot be rebased to reflect cost efficient tariffs.

#### ***2.5.4.4 Electricity debt collection and debtor-days***

As a common practice worldwide, utilities usually supply electricity and later send invoices to consumers, indicating the period within which the electricity bills must be settled. The number of days a customer of electricity is given by the electricity supplier to settle the debts is referred to as “Debtor days”. “Debtors days” in Zambia are more than those in any other Southern African countries. For example between 2005 and 2006, the debtor days in Zambia were 207 whereas in South Africa were 22 days (SAPP 2006).

## **2.6 CHALLENGES FACING THE ELECTRICITY MARKET**

From the preceding discussion it is clear that the Zambia electricity market is faced with management and structural weaknesses among which are: (i) problems related to capital investment requirements, (ii) Sub-economic tariffs, (iii) government interference, (iv) the monopolization of the market by ZESCO, (iv) utility inefficiency, and (v) lack of demand side management.

### ***2.6.1 Capital Investment Requirements***

The electric power project requirements are a source of concern in Zambia. Sisala (2008) observes that power projects in Zambia (i) have long gestation periods, (ii) are subjected to cumbersome pre-feasibility and feasibility studies plus Environmental Impact Assessments, (iii) have long implementation periods (usually 5 to 7 years), (iv) require huge capital outlay, (v) are characterized by long payback periods contrary to the private sector demands of short term returns, and (vii) compete for capital with more lucrative projects with short term returns.

### ***2.6.2 Sub-Economic Tariffs***

As already discussed, electricity tariffs in Zambia are too low and not cost reflective. Raising electricity tariffs to make them cost effective is a very sensitive political issue in Zambia. Attempts to increase tariffs have been opposed on the ground that the cost of doing business especially for those businesses that are energy intensive will be higher. Compounding this problem is the inability by Zambia to attract private investment in the electricity sub-sector which has been attributed to Zambia having one of the lowest tariffs in the region. The estimated value of investment that Zambia needs to attract within 5 years in order to attain a generation capacity of 4,500MW is US\$6 billion (ZESCO 2009).



### **2.6.3 Government interference**

Although Government intervention has been positive in wanting to address power shortages, yet it has failed to create a competitive electricity market partly because of its gross failure to commercialize ZESCO and by its heavy tolerance of sub-economic tariffs.

The efforts by utilities to raise electricity tariffs are to large extended prevented by the current legal system in Zambia, which is dominated by the Government interference. The entire Section 8 of the Electricity Act Chapter 433 of the Laws of Zambia empowers ERB to either confirm the proposed variation in electricity tariffs by suppliers of electricity , or order that the proposed variation shall not be made or order the operator of the undertaking to make such other variation as the Board considers fit.

ON several accounts, GRZ has been accused of its gross failure to manage ZESCO and its of ZESCO to advance its political agenda. In 2009, for example, an article on “ZESCO Blackouts is MMD Failure” by Zambian Union blamed the Government as follows:

ZESCO’s failure to deliver is due to misguided government energy goals and lack of effective political leadership. The MMD government has not prioritized to fix the electricity supply crisis to avoid blackouts and save government spending on importing power.

In a nutshell, appropriate Government intervention is necessary, though not sufficient, to revitalize the electricity market in Zambia.

### **2.6.4 Monopolization of the electricity market**

As already highlighted, ZESCO is the biggest electricity utility in Zambia, owning most of the generation, transmission and distribution assets. That Zambians have urged Government to review the monopolization of ZESCO has been on political agenda for decades. On 4 May 1999, for example, an article on “ZCC to probe ZESCO monopoly” in the national newspaper, Times of Zambia, reported as follows:

The Zambia Competition Commission (ZCC) is looking forward to engaging an independent consultant to ascertain the extent of abuse of monopoly by Zambia Electricity Supply Corporation (ZESCO). ZCC executive director Mr. George Lipimile confirmed this in an interview saying the action has been necessitated by recent complaints from the Zambia National Farmers Union (ZNFU).

In 2009 an article on “ZESCO Blackouts is MMD Failure” by Zambian Union stresses that ZESCO enjoys market monopoly and revenue to update its grid system; unless that revenue is misappropriated for personal and political interests.

Although the economic theory entails that in the presence of market power suppliers have the ability to set prices above the cost of the last unit produced, yet this is not the case with ZESCO monopoly mainly because electricity prices are largely determined by ERB.

#### **2.6.5 *Utility inefficiencies***

The largest utility, ZESCO, has been unable to invest in new generation capacity because it lacks resources. In addition, the utility has been run inefficiently and finds it difficult to borrow from international financial institutions. The inability to access funds and not being able to generate sufficient internal resources has led to the delay in maintenance programs which has affected the quality of supply. This has resulted in the persistence of the power deficit. In addition, ZESCO costs have been escalating over the years with the highest portion of their cost of distribution being staff costs. ERB (2007) reports as follows:

We found that during the financial year ended 31st March 2007, labour costs were the biggest component of operating costs which contributed 49%. The proportion of labour costs to the total budget is way beyond acceptable international levels which is about 30%. We therefore find that there is an urgent need for ZESCO to begin reducing its labour cost and in this regard have decided to adjust this labour cost contribution to operating costs to 40% for 2008, 35% for 2009 and 30% for 2010 after excluding extraordinary costs like electricity imports, loan interest rates and taxation.

That the efficiency and accountability of ZESCO is questionable has resulted in the resistance to an increase in tariffs by the business community. International Monetary Fund (IMF) has strongly admitted that ZESCO is financially unviable and incapable of mobilizing resources owing to its bad track record and even though it managed to increase its tariffs it would still be unviable.

Statistics show that that the total receivables for ZESCO appear to be increasing yearly. For example, total receivables increased from 35% of turnover in January 2008 to 61 per cent of turnover in September 2008. The target for transmission losses was met for 2008. Transmission losses were at 4.5 per cent while distribution losses are above 33 per cent. Though the utility has been commercialized its internal operations leave much to be desired.

As a result ZESCO is perceived badly by the business community who feel that the utility should first clean up its act before requesting for any increase in tariffs (ZESCO 2008).

### ***2.6.6 Lack of demand side management***

As already highlighted, electricity demand side management is lacking in Zambia for various reasons. In addition, Zambia does not have a deliberate policy on energy efficiency, a reflection of non commitment on the part of the Government to steer the nation towards energy management; and the energy services introduced by ZESCO (free of charge energy audits to consumers; and Time of Use tariff for Maximum Demand consumers) have not been used by consumers (Sisala 2008).

## **2.7 CHAPTER SUMMARY**

In this chapter I have key issues on electricity market in Zambia. First, Zambia has a national policy and legislative framework on electricity: the 1994 National Energy Policy; the Fifth and Sixth National Development Plan; Energy Regulation Act of 1995; the Rural Electrification Act of 2003; the Electricity of 1995; the Electricity (Amendment) Act of 2003, and Petroleum Act of 1930.

Second, electricity is one of the seven subsectors of the energy sector in Zambia. Other subsectors are wood fuel, electricity, petroleum, coal, renewable energy, and other forms of energy. Wood fuel consumption commands the largest consumption, followed by electricity and then Petroleum.

Third, there are currently three suppliers of electricity in Zambia: Zambia Electricity Supply Corporation Limited; Copperbelt Energy Corporation; and Lunsemfwa Hydro Power Company; Zengamina Hydro Power Company; and North-western Energy Company Ltd situated in North-western Province. However, ZESCO - a vertically integrated public utility, involved in generation, transmission, distribution and supply of electricity - dominates the market.

Fourth, annual electricity maximum demand in Zambia has been increasing. The main drivers of increased electricity demand and deficit in Zambia include Economic Growth of more than five per cent in most of the SADC member countries resulting in unprecedented growth in electricity consumption and demand; increased demand for base metals resulting in high metals prices on world market; establishment of new and expansion of existing mining

companies; growth in other sectors such as industry, commerce, agriculture and housing; country wide electrification programs – rural and urban; and inadequate investment in generation and transmission infrastructure over the last 20 – 30 years. However, the increased demand electricity as been coupled with power deficits in electricity staring 2008.

Fifth, the mining in Zambia is the largest consumer of electricity, accounting for more than 50%.

Sixth, electricity tariffs in Zambia are not cost effective and the mines are under priced by ZESCO, an act whose continuation over the next 10 years could result in a US\$926 million deficit relative to ZESCO's revenue. In addition to low tariffs, Zambia has more debtor days (207 days) than any other country in the Southern African.

Lastly, energy subsector in Zambia, especially the electricity subsector, faces several challenges: the problems related to capital investment requirements; sub-economic electricity tariffs; government interference in setting electricity tariffs; monopolization of the electricity market by one entity (ZESCO); utility inefficiency; and weak demand side management.

In the next chapter I will describe Zambia's industry and its linkages with the electricity.

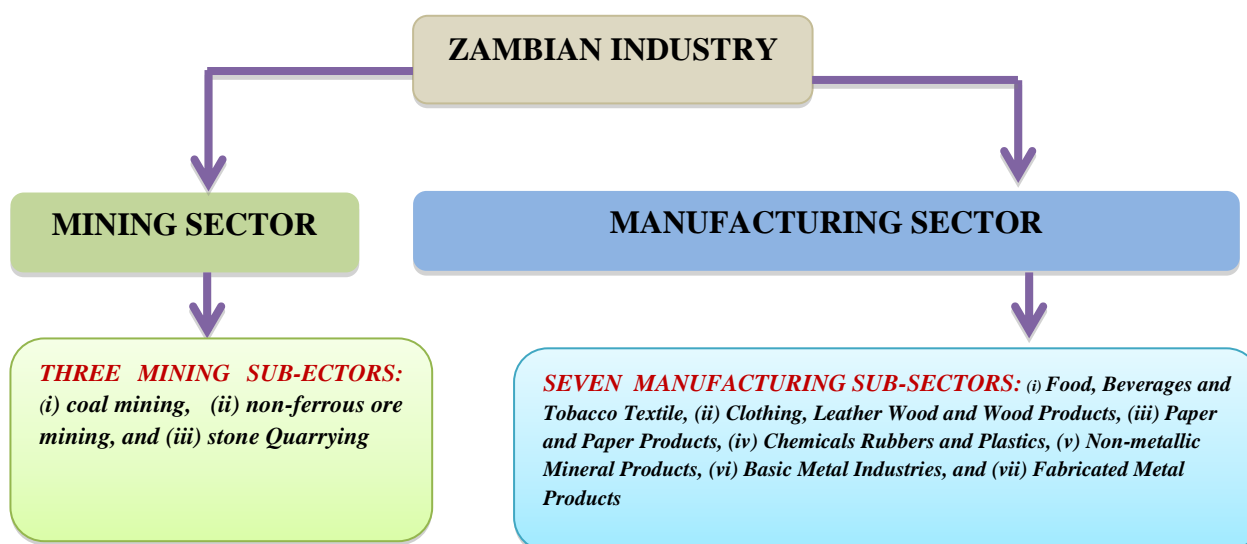
### 3.1 INTRODUCTION

The industry (comprising mining sector and the manufacturing sector) is the backbone of Zambia's economic structure. When Zambia shifted from a one-party state to a multi-party state in 1991 four ideologies were introduced in its industry: (i) *privatization* (transfer of state owned companies and industries to private individuals and companies in order to encourage competition and increase efficiency in the industry); (ii) *liquidation* of companies (bringing unprofitable state owned companies and businesses to an end); (iii) *liberalization* of the economy (absence of government intervention in businesses); and (iv) *withdrawal of subsidies* from loss making companies and introduction of cost sharing measures.

This chapter describes the industry in Zambia. In particular, Section 3.2 presents a graphical illustration of the industry in Zambia; Section 3.3 describes relevant issues on mining sector; Section 3.4 describes the manufacturing sector, and Section 3.5 provides the chapter summary.

### 3.2 CONCEPTUALIZING THE INDUSTRY IN ZAMBIA

*Figure 2: Diagrammatic conceptualisation of Zambia's industry*



*Source: Author's compilation (Based on information from the CSO)*

As shown in Figure 2 the industry in Zambia comprises two sectors: Mining and manufacturing. These two sectors are further divided into subsectors shown above.

### 3.3 MINING SECTOR

In recent years the mining sector in Zambia has experienced rapid growth and it is hoped that more mines will be opened. Zambian government explains as follows:

The mining industry has experienced exceptional growth averaging 9 per cent per annum in the last decade and prospects for further development are enormous. The sector will, therefore, continue to be a major driver of growth, while also providing impetus for value addition through the creation and expansion of the manufacturing industry. In addition, this is expected to create spill over effects through development of necessary infrastructure, especially those related to roads, railways, border facilities and reliable electricity supply. This will be complimented by redesigning of policies so as to encourage and attract private investment in exploration, re-investment and development of new mines through a stable and attractive fiscal and regulatory regime (Ministry of Finance, Planning and National Development 2010: 10) .

Zambia has potential for the expansion of the mining sector because it has many minerals deposits and a steady investment environment. At present, Zambia is the largest producer of copper in Africa. Sophie Chung, an analyst at Wood Mackenzie unit Brook Hunt (as quoted by *Mining Review* 11<sup>th</sup> July 2011) explains that if all the planned projects take off, Zambia is expected to overtake Australia and Indonesia to become the fifth-largest copper-producing country in the world by 2013. Chung goes on to add that Zambia's "positive" investment climate sets it apart from its neighbours. In addition, many mining companies in Zambia have managed to enter into extremely good development deals in their contracts. The agreements include incentives such as favourable power rates and unrestricted ownership (Lushinga, an economist at the Economics Association of Zambia, as quoted by *Mining Review* 11<sup>th</sup> July 2011).

#### 3.3.1 Minerals found in Zambia

Zambia has an enormous amount of metals, gemstones, industrial minerals and potential energy resources, including coal, hydrocarbons and uranium. For several years, Zambia's economy has been based on mining, predominantly copper and cobalt. In fact, the minerals in Zambia comprise three categories: industrial minerals, dimension stones and metal (base) stones. Industrial minerals include, *coal* (in the Mid-Zambezi Rift Valley); *limestone* (in Lusaka, Southern, North Western, Northern and Luapula Provinces); *phosphate* (in Eastern Province); *silica sand* (in Kapiri Mposhi); *barite* ( in Luwingu, Lundazi and Chirundu districts); *corundum* (in Rufunsa area); *fluorite* (in Siavonga district); *graphite* (in Lundazi

and Chama districts); and *Uranium* (in Western and North-western provinces). Dimensions stones in Zambia are the marble, granite and slate stones. Granite and marble are used in building construction. Slates are used as used for paving, panelling, floor tiles and for high-quality slate in architectural work. The main base minerals in Zambia are Cobalt, Copper, Silver, Gold, Tin and Zinc.

Although, I have stated a lot of minerals above, I should emphasize that copper mining is the lifeblood of Zambia's economy, contributing nearly three-quarters of its foreign exchange earnings.

### ***3.3.2 The Copper mines in Zambia***

China is the biggest investor in the mining sector in Zambia. China has sunk more than \$2 billion into the sector. There are four Chinese-run copper mining companies in Zambia, all subsidiaries of China Non-Ferrous Metals Mining Corporation (CNMC), a state-owned enterprise: (i) Chambishi for Non-Ferrous China Africa (NFCA); (ii) Sino Metals Leach Zambia (Sino Metals), a copper processing plant; (iii) Chambishi Copper Smelter (CCS), a copper smelting plant; and (iv) China Luanshya Mine (CLM), an underground and open-cast mining operation.

Other mining firms in Zambia include Canada's First Quantum Minerals and Barrick Gold (own Kansanshi Copper and Gold mines in North-western Province, and Bwana Mkubwa mine on the Copperbelt Province); Australia's Equinox Minerals (own Lumwana Mine), London-listed commodity giant Glencore and Vedanta Resources (own Konkola Copper mines), and South Africa's Metorex.

The Chinese investments in Zambian mining sector have raised great concern to human rights activists. The Human Rights Watch (HRW) Director, Daniel Bekele (as quoted by BBC News Africa, December 3, 2011), commended that China's significant investment in Zambia's copper mining industry can benefit both Chinese and Zambians. Bekele went on to expose that the miners in Chinese-run companies have been subject to abusive health, safety, and labour conditions and long-time government indifference. The research by HRW (2011) detailed persistent abuses in Chinese-run mines, including poor health and safety conditions, and regular 12-hour and even 18-hour shifts involving arduous labour, all in violation of Zambian law. The report cites an example in which 11 workers were shot and injured during a pay dispute at a Chinese-run mine in 2010 and that five others were hurt during a similar confrontation at a different mine in 2005. The report further illuminates that miners had to

work 12-hour shifts often in fume-filled tunnels and sometimes shifts were 18 hours long; contrary to the Zambian law, which limits shifts to eight hours.

Significant to this study is that the mining sector is the largest consumer of electricity in Zambia. Mining processes are electricity-intensive. Implicitly, electricity demand in mines is likely to be inelastic. Also any interruption in electricity supply impacts the mines negatively. For example, the power blackout on June 18, 2011 was reported to have negatively impacted mine operations. This blackout, reported as the first of its kind since 2009, made copper producers lose revenue amounting to millions of US dollars. The day after the blackout Vedanta's Konkola mine, one of the country's largest, stated that its employees were still working to pump out underground water that had flooded the mine during the blackout. Similarly, First Quantum's Bwana Mkubwa mine stated that a lot of their electrical equipment was damaged because of unstable supply when the power was restored - but they were yet to calculate the full extent of the losses (Mfula, as quoted by Reuters on June 19, 2010).

In general, electricity is a necessary input in the copper mines Zambia.

### **3.3.3 Mineral processing and electricity use**

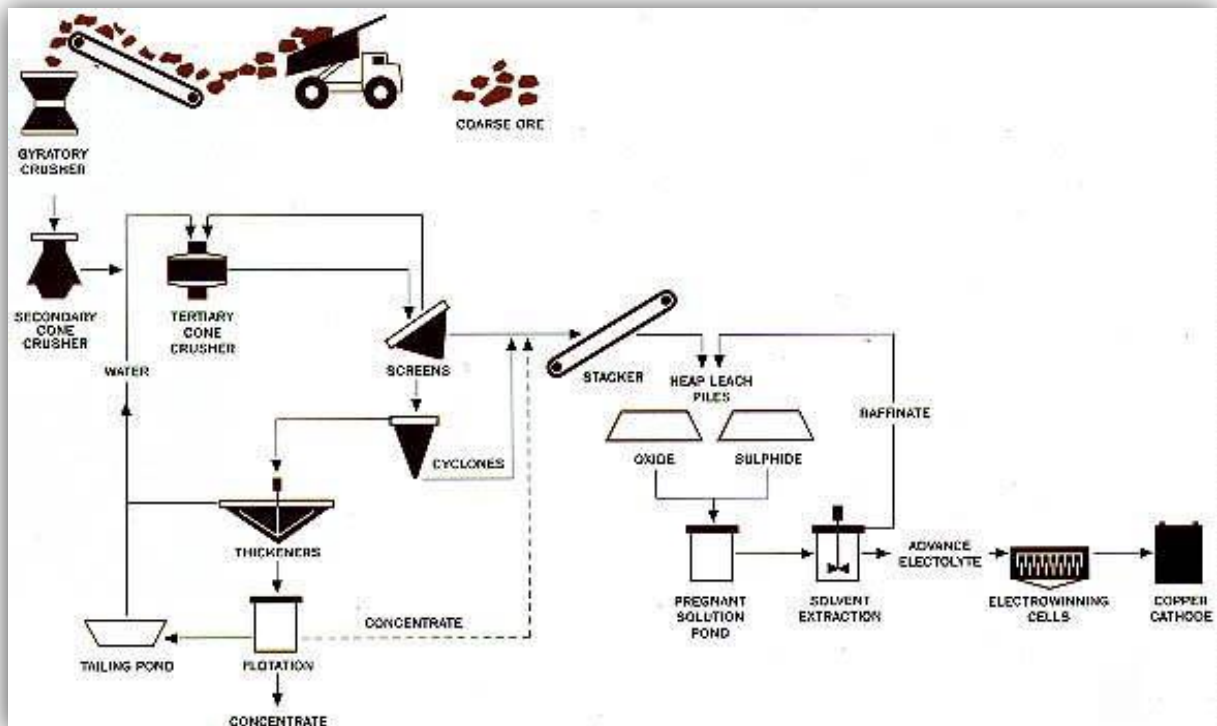
As a major base metal mining country of over 80 years standing, Zambia has over the years developed an extensive and impressive array of processing facilities. The processes include ore mining process; beneficiation process (crushing and separating ore into valuable substances or waste by any of a variety of techniques); smelting process; and refining process into metals prior to export. In addition, the leaching process helps recover cobalt from the slurry, and mined gemstones are processed in lapidaries. For example, Zambia Emerald Industries Limited has developed to one of the largest emerald processing and cutting plants in the world with over 50 cutters under one roof. Electricity is an important input in these processes.

Figure 3 shows the basic copper mine process, from ore extraction to metal. The copper ore from a mine is blasted, loaded and transported to the primary crushers (*crushers usually run on electricity*). Then the ore is crushed and screened, with the fine sulphide ore to froth flotation cells for recovery of copper (*here electricity is used*). The coarser ore goes to the heap leach, where the copper is subjected to a dilute sulphuric acid solution to dissolve the copper. Then the leach solution holding the dissolved copper is exposed to a process called solvent extraction (SX) (*here electricity is used*). The SX process concentrates and purifies



the copper leach solution to enable the recover of copper at a *high electrical current efficiency* by the electrowinning cells.

**Figure 3: A basic copper mine process -from mine to metal**



Source: Copper Mine Engineer (<http://www.mine-engineer.com/mining/copperm.htm>)

Other processes in mining are those employed by quarries. Zambia has many quarries. Among the prominent quarries found in Zambia are the United Quarries Limited (in Lusaka), Oriental Quarries Limited (in Lusaka), Namulundu Quarries Limited (Lusaka), Shimabala Quarries (in Kafue), Southern Quarries (in Livingstone). These quarries have crushers which are driven by electricity. Thus, electricity is a necessary input in the processes at the quarry.

All in all, electricity is a necessary input in mineral processing in Zambia.

### 3.4 MANUFACTURING SECTOR

The manufacturing sector in Zambia comprises seven subsectors: (i) Food, Beverages and Tobacco Textile, (ii) Clothing, Leather Wood and Wood Products, (iii) Paper and Paper Products, (iv) Chemicals Rubbers and Plastics, (v) Non-metallic Mineral Products, (vi) Basic Metal Industries, and (vii) Fabricated Metal Products.

Regarding the role of manufacturing in Zambia's economy during the period 2010-2015, GRZ states that main thrust during the SNDP period will be to facilitate the up-scaling of the manufacturing sector towards higher value addition and upgrade capacity in the provision of related services. Emphasis will be placed on transforming industrial businesses and complementary services particularly MSMEs into strong value-creating entities (MOFNP 2010: 133)

The government goes on to indicate its displeasure with the manufacturing sector's contribution to GDP during the period 2006-2010: 10.2 per cent against the target of 15 per cent. Also government was not impressed with the sector's annual growth during the same period: an average of 3.3 per cent was achieved against the projected growth of 7.5 per cent. In short, the growth rate of the manufacturing sector declined from 5.8 per cent in 2006 to 2.5 per cent in 2009 (MOFNP 2010: 133).

Generally, the causes of the decline in the performance of the manufacturing sector are many. The government first place the blame of overall decline in the manufacturing sector on significant drops in productivity in the textiles and clothing, leather and leather products and fabricated metals sub-sectors. They suspect that this drop in productivity was largely due to the high cost of doing business; reduced demand for locally produced products and the impact of the global economic crisis.

The government second blames a lot of factors for the decline in the performance of the manufacturing sector: high cost of doing business largely on account of poor physical infrastructure and high production costs; disruptions in power supply; low investments in Research and Development; obsolete technology; high cost of borrowing; limited standardisation and quality assurance; and limited human capital and skills required to run the manufacturing industry on a sustainable basis (MOFNP 2010: 135).

Having interacted with the Zambia market since my childhood, I am of the opinion that the decline in the performance of the manufacturing sector is partly due to the religiously-low-priced goods imported from Asian countries. In fact, cheap goods from China have attracted worldwide attention and court cases. On 25 October 2011, for example, China initiated a court case against the United States at the World Trade Organization on Tuesday, arguing that U.S. anti-dumping measures on imports of diamond saw blades and frozen warm-water shrimp were invalid. The United States had previously placed anti-dumping duties on imports of the products from China, claiming that they are deliberately priced below the market and killing off U.S. competition. Similarly, on 28<sup>th</sup> October 2011 a World Trade Organization panel largely backed China in a complaint about European Union import duties on Chinese

footwear. The case is the second brought by China against the EU at the WTO. In July 2011, China won a similar case against EU duties on what Europe said were unfairly cheap Chinese screws and bolts.

However, not all subsectors in the manufacturing sector have performed poorly. The food and beverages sub-sector, for example, grew and sustained the sector's contribution to the total GDP during the period 2005-2010. This growth is linked to increased investments resulting from companies expanding their plant and the proliferation of stream of industries which process edible oils.

To address the problems in the manufacturing sector, the government has stated its strategic will be to strengthen and widen the country's manufacturing base with emphasis on backward and forward linkages given the country's wide resource base. This will require intensifying the development of the resource-based industries, with the aim to optimise and add value to the country's natural resources. In line with the strategic focus of the Plan, emphasis will be to enhance competitiveness of manufacturing through infrastructure and human development to support growth of the sector (MOFNP 2010: 135).

In sum, the significance of the above discussion to this study is that most of the production processes within various subsectors of manufacturing sector in Zambia use electricity. It is also cardinal to know the effect of aggregation of the manufacturing subsectors on the interpretations of the study results.

### **3.5 CHAPTER SUMMARY**

This chapter has presented salient issues on both the mining and manufacturing sectors of Zambia's industry. Zambia is the largest copper producer in Africa. The Chinese investment, whose operations have criticized as not upholding the human rights, dominates the mining sector. Significantly, mining is an electricity-intensive sector and the highest consumer of electricity in the Zambia.

The manufacturing industry comprises seven subsectors, ranging from Food, Beverages and Tobacco Textile, to Fabricated Metal Products. During the last decade, the sector's contribution to the GDP has declined contrary to the expectation of the government. Reasons for this state of affairs are varied: high cost of doing business; reduced demand for locally produced products and the impact of the global economic crisis. The government has formulated strategies to boost the sector. Significantly, many processes in manufacturing

sector depend on electricity. In addition, the presented trends illuminate my interpretation of the study results.

### 4.1 INTRODUCTION

This chapter presents literature related to the study purpose: *to examine the electricity demand in Zambia's industry by focusing on price and output elasticities of electricity demand and structural changes in demand patterns over the period 1980-2008; and to expose any energy efficiency development in the Zambian industry.* In this regard, there are four contemporary literatures within which this study may be placed: (i) general literature on industrial electricity modelling; (ii) general literature on energy efficiency in industries; and (iv) literature on efficient use of electricity in industry sector in Zambia.

The sources of literature include the recommended study materials for the program I am enrolled in at the University of Oslo (Master of Philosophy in Environmental and Development Economics); published books, mainly from the University of Oslo Library; scientific online journals; Zambia Electricity Supply Corporation Limited (ZESCO) and Zambia Energy Regulation Board (ERB); and several databases including the US Energy Information Agency.

Undeniably, literature on industrial electricity demand as well as energy efficiency in industries is extensive and has become more complicated with the passage of time. This complication demands me to put the literature in context. To do so, I proceed as follows: Section 4.2 presents the literature on industrial electricity demand; Section 4.3 covers literature on energy efficiency in industries in; and lastly, Section 4.4 provide the chapter summary.

### 4.2 INDUSTRIAL ELECTRICITY DEMAND

#### 4.2.1 *General literature on industrial electricity demand*

There is rich literature on energy demand modelling, in general, and on industrial electricity demand modelling, in particular. Several studies on industrial electricity demand have been conducted at various aggregation levels, on various times and using different models and variables.

Certainly, the models for studying electricity demand have evolved. Morana (2007) on “Factor demand modelling: the theory and the practice” explains the two key innovations that

introduced from the time Cobb and Douglas (1928: 139-169) presented their seminal work on the theory of production. These two innovations are (i) the use of static-flexible functional forms and (ii) the modelling of dynamics, expectations, and the interrelatedness of the adjustment process.

The first innovation aimed at relaxing the a priori assumption of unitary elasticities of substitution for all the factors of production characterizing the Cobb-Douglas formulation (Morana 2007). The introduction of flexible-functional forms achieved this aim. Examples of these forms are the generalized constant-elasticity-of-substitution (CES) form by Denny (1974); the nested generalized Leontief form by Fuss (1978); the generalized Cobb-Douglas function by Diewert (1973); and the non-separable nested CES by Perroni and Rutherford (1995).

The second innovation aimed at promoting modelling of dynamics Morana (2007: 1520). The introduction of three categories of dynamic factor demand models - first, second and third generation models - (Berndt et al. 1981) achieved this aim. The dynamic specifications in the first-generation and second-generation models are determined empirically. The specifications of the adjustment process in the third-generation models are derived from a clear theoretical framework.

Flexible-functional forms are useful in analyzing electricity demand in industries. However, the suitability of different forms depends on the purpose of the model, the available resources for studies, and the available data for testing model.

Generally, the major focus for many studies on electricity demand is to estimate the elasticity of demand. Table 6 presents the summary statistics for studies that used dynamic models. Conclusively, electricity demand is more elastic in the long run than the short. The long run denotes the period during which all factor inputs are variable. The short run denotes the period during which at least one factor input is fixed but other factor inputs are variable.

**Table 6: Summary statistics on elasticities for the studies that use dynamic models**

All electricity		Price <sub>sr</sub>	Price <sub>stat</sub>	Price <sub>lr</sub>	Income <sub>sr</sub>	Income <sub>stat</sub>	Income <sub>lr</sub>	Q <sub>t-1</sub>
	Average	-0.21	-0.44	-0.48	0.32	0.58	1.08	0.60
	Median	-0.14	-0.34	-0.37	0.30	0.44	0.88	0.66
	Std Deviation	0.41	2.50	3.26	0.39	1.56	9.13	0.30
	1 <sup>st</sup> Quartile	-0.28	-0.74	-0.82	0.10	0.11	0.46	0.47
	3 <sup>rd</sup> Quartile	-0.04	-0.07	-0.10	0.46	0.96	1.07	0.79
	Count	1450	3317	1639	1048	1377	1179	1010
<b>Note:</b> sr = short run; lr= long run; and Qt-1=coefficient on the lagged endogenous variable in dynamic models; stat=static model Source: Adapted from Dahl (2011)								

In Table 6, the median elasticities for both income and price are in the inelastic region with averages all a bit more elastic. The median elasticities for all but  $Qt-1$  are less elastic than the means with the discrepancy largest for the long run for both price and income. Both the average and median estimates suggest a less elastic response to price than to income.

Certainly, Table 6 does not provide detailed information on the issues surrounding explanatory variables that have been modelled frequently in industrial electricity demand. Thus, the remaining part of this section focuses on the both the explanatory variables and the key findings of several studies on industrial electricity modelling.

First, studies have revealed that electricity demand response to changes in electricity price vary across industries (see, for example, Lafferty et al. 2001; Wolak and Patrick 1996). Lafferty et al. (2001: 13) explain that price elasticity of electricity demand vary widely across different industries and as such, a region cannot expect demand response from the industrial sector to match that of another region unless the mix of industries is similar. Similarly, Wolak and Patrick (1996) estimated the customer-level demand for electricity by industrial and commercial customers purchasing electricity according to half-hourly energy prices from the England and Wales electricity market. They found that price elasticities varied considerably across industries.

Second, many previous studies have indicated that weather conditions and the time of use of electricity have a considerable effect on electricity demand in industries (see, for instance, Fan and Hyndman 2010; Cebula and Herder 2010; Hansen 2004). Fan and Hyndman (2010) evaluated the historic South Australian price elasticity, focusing on the relationship between price and demand quantities at each half-hour of the day. They attempted to determine whether there is any variation in price sensitivity with the time of day, and to estimate the form of any relationships that might exist in South Australia. They found that the overall price elasticity ranged from -0.363 to -0.428, with strongest price responsiveness approximately at the peak period; around 4 O'clock in the afternoon for summer and 7 O'clock in the evening for winter.

Cebula and Herder (2010) employed the three panel two-stage least squares (P2SLS) in identifying key economic factors and other conditions that have influenced the per customer commercial and industrial consumption of electricity in the U.S. for the period 2002 through 2005. They found that per customer commercial and industrial electricity consumption is an increasing function of the annual number of cooling degree days and the peak summer electricity generating capacity.

Similarly, Hansen (2004) analysed the aggregate spot-price elasticities for 8 different regions in Norway. Price elasticities for different weekdays and load periods were estimated. Hansen found that the long run price elasticities for the regions were in the range from 0 to -0.12 in the winter season, and between 0.12 and -0.05 in the summer season. Thus, in Norway, more electricity is demanded in winter than summer.

In general, there is strong seasonality in the electricity demand, especially in high frequency data such as daily or monthly. Stochastic seasonality, as revealed by Engle et al. (1989), results in the inconsistent estimation of the parameters in a regression. However, such inconsistency problem can be overcome by filtering the data: either by altering data periodicity (for instance, from daily or monthly to annual data), or by taking differences of the variables in the seasonal frequencies (Chang and Martinez-Chombo 2003: 9). Alternatively, seasonality can be directly modelled by choosing a variable that captures the seasonal component of the electricity demand. Temperature related-measures such as the number of heating and cooling days per period and the average temperature are standard candidates for such variable.

Third, studies have shown that inter-fuel substitution, especially between oil and electricity, is an ancient interest to both economists and politicians, especially for evaluating sustainability capacities and in approximating the economic cost of environmental policies. However, there are mixed results from earlier studies on inter-fuel substitution by industries. Some studies (see for example Fuss 1977; Deshpande 1966; and Steinberg 1954) have shown little inter-fuel substitution. In contrast, some studies (see, for example, Halverson 1976; Griffin 1977); and Uri 1977) have suggested significant amount of inter-fuel substitution.

In general, recent studies have shown potentials for inter-fuel substitution (see, for example, Bölük and Koç 2010; Førsund 2007: 10; Stern 2009). Bölük and Koç (2010) modelled factor demand for manufacturing sector in Turkey by estimating a translog cost function with four factors (capital, labour, intermediate input and electricity) for the period 1980–2001. They found that substitution possibilities existed between electricity and intermediate input. Implicitly, changes in the price of intermediate input can affect electricity demand.

Førsund (2007: 10) notes that in industries boilers can be run on alternative energy sources including electricity and that can be switched from one source to another in a relatively short time.

Stern (2009) conducted a meta-analysis of studies done on inter-fuel substitution in industrial sector. Stern sampled 47 studies in manufacturing industry or manufacturing sub-industries, or



in the macro-economy of a variety of developed and developing countries. Meta-regressions for the six shadow elasticities of substitution between coal, oil, gas and electricity were estimated. Stein found that oil–electricity and gas–electricity shadow elasticities of substitution were significantly greater than unity.

Some studies that have compared the possibilities for inter-fuel substitutability in the long-run and than short run indicate that more inter-fuel substitutability possibilities exist in the long run than the short run. Stern (2009), for example, concluded that the typical definitions of elasticities of substitution are founded on long-run responses and, consequently, long-run estimates are desirable. In this respect, panel data studies tend to find more inter-fuel substitutability than time-series studies because panel data is associated with long-run elasticities and time-series data short-run elasticities. Specifically, Bacon (1992) after surveying some of the early studies of inter-fuel substitution elasticities in the OECD countries concluded that panel data studies tend to find more inter-fuel substitutability (measured by fuels' cross-price elasticities) than time-series studies.

In a nutshell, whether electricity can be substituted for other fuels mainly depend on the nature of the country's electricity sector. Generally, many studies that have found the price of substitute significant in their analysis subscribe to the assumption that fuels, such as diesel, present perfect substitutability with electricity and that their prices are affordable and preferred rather than electricity (Anderson and Hsiao 1982; Anderson and Pomfret 2002;).

Fourth, the time trend variable as been used widely in the industrial electricity demand models (see, for example, Dimitropoulos, Hunt and Judge 2005; Hunt, Judge and Ninomiya 1999).

Dimitropoulos, Hunt and Judge (2005) estimated the underlying energy demand trends using annual data for the UK from 1967-2002. They employed the structural time series model (STSM) approach. They confirmed that important non-linear and stochastic trends are present as a result of technical change and other exogenous factors driving demand, and that a failure to account for these trends will lead to biased estimates of the long-run price and income elasticities. They established that, provided these effects are allowed for, the estimated long-run elasticities are robust to the different data frequencies used in the modelling. Thus a time trend variable is important in electricity modelling.

Literature informs us that technical progress in electricity use does not forever exhibit a deterministic trend pattern as the conventional model assumes. Hunt, Judge and Ninomiya (1999), for example, have argued that the deterministic time trend, as a conventional model, fails to predict the precise role of technical progress in estimated energy demand functions.

They go on to argue that a conventional deterministic trend model cannot be accepted by the data for a number of energy types. To substantiate their argument, Hunt, Judge and Ninomiya estimated the energy demand functions for a variety of energy types for the UK using unadjusted quarterly data. They found that technical progress in energy usage does not always exhibit a deterministic trend pattern as the conventional model assumes. It often fluctuates over time and is likely to be influenced by an array of exogenous factors but also by changes in prices of energy.

Last, there are mixed study results on whether income elasticities are bigger than price elasticities of industrial electricity demand. As already seen in the summary statistics in Table 2 show, average income elasticity is greater than price elasticity. However, some individual studies have shown that income elasticity is less than price elasticity (see, for example, Baxter and Rees 1968; Inglesi 2008; Dilaver and Hunt 2010).

Baxter and Rees (1968) estimated electricity demand by industry on quarterly time series data for the U.K. using a dynamic model. They found that the electricity demand tended to be more price than income elastic.

Inglesi (2008) conducted a study to specify the variables that explain the electricity demand in South Africa and to forecast electricity demand by creating a model using the Engle–Granger methodology for co-integration and Error Correction models. She found that the long-term elasticity of price (-0.55) was bigger than that of income (0.42), although they were both estimated to be inelastic.

Dilaver and Hunt (2010) applied the structural time series technique to annual data over the period 1960 to 2008 to forecast the future Turkish industrial electricity demand. They investigate the relationship between Turkish industrial electricity consumption, industrial value added and electricity prices. They found that the long-term elasticity of price (-.16) was bigger than that of income (0.15). They further forecast Turkish industrial electricity demand somewhere between 97 and 148 TWh by 2020.

In sum, the general literature on industrial electricity demand discussed above is relevant to the current study in the study because they have covered most of the explanatory variables this study has used: price of electricity, price of fuel, and time trend. Having stated so, I will now proceed to review literature on industrial electricity demand in Zambia.

#### 4.2.2 Literature on industrial electricity demand in Zambia

Unlike charcoal (see, for example Chidumayo 1988, 1990, 1991, 1993, 2004; Syampungani et al 2008), electricity demand in Zambia has not been widely studied. Scientific journals, for example, do not contain many studies on electricity in Zambia: (Haanyika 2008; IPA Energy Consulting 2007; Jain and Munyeme 1994; Kalumiana 2002; Ranganathan and Mbewe 1995). Table 7 summarizes the purpose and findings of these each study.

**Table 7: Summary of studies on electricity in Zambia**

AUTHOR	TITLE/PURPOSE	FINDINGS
Haanyika (2008)	<p><i>Rural electrification in Zambia: A policy and institutional analysis:</i></p> <p>Analyse the policy, legal and institutional measures implemented in Zambia and assesses their potential or effectiveness to tackle some of the challenges facing rural electrification in the country so as to increase access and affordability.</p>	The rural electrification policy had facilitated increased decentralized technologies, supplying of remote towns and villages with electricity from solar PV; and increased financial resources for rural electrification; reduced cost of electricity distribution networks. However, the capacity to implement rural electrification policy measures was not enough.
IPA Energy Consulting (2007)	<p><i>Cost of Service Study on Zambia Electricity Supply Company (ZESCO).</i></p> <p>This study was a major component of the Project sponsored by the World Bank and SIDA to strengthen the capacity of the Zambia Energy Regulation Board.</p> <p>Enable ZESCO and the Zambia Energy Regulation Board (ERB) to develop a deeper understanding of ZESCO's cost structure, cost drivers, and its revenue requirements that need to be reflected in appropriate tariff levels so that ZESCO can meet the Government's commercialization objectives and therefore its supply obligations in the future</p>	ZESCO had been under pricing the mining load, which, at the time of the study, represented 50% of total consumption in Zambia. In addition, under priced contracts for Copperbelt Energy Corporation including the new contracts ZESCO was entering into with new retail mining loads. IPA Energy Consulting recommended that ZESCO must urgently increase electricity tariffs (by 150 %) and control its costs.
Kalumian (2002)	<i>Policy Options for Increasing Electricity Access for Poor Urban Households in Zambia</i>	Out of the four main fuels (electricity, charcoal, firewood and kerosene), electricity was subsidized heavily by the Zambian Government
Ranganathan and Mbewe (1995)	<p><i>Feast and famine: The case of Zambia's power sector</i></p> <p>Outline the causes for the sickness for the Zambian power sector</p>	The Zambian power sector had almost nothing under its control. Electricity tariffs were decided by exchange rate fluctuation of the Zambian currency (Kwacha) and world price of copper. The authors argued that the mining sector were likely to pay more to the power sector.
Jain and Munyeme (1994)	<p><i>Energy scenario of Zambia: prospects and constraints in the use of renewable energy resources.</i></p> <p>Describe and analyze the state of energy resources, supply and demand in Zambia</p>	Photovoltaic power had been put to some practical applications in Zambia. Hydropower continued to remain the mainstay of Zambia's electricity supplies. The authors recommended that renewable energy sources should be exploited for applications in remote areas.

The “electricity tariffs” in Zambia is an issue of technical and economic concern. That the tariffs are not economically efficient is well documented. In this vein, ERB considered and approved ZESCO’s proposal for multi-year (2008-2010) electricity tariff adjustment rates. Table 8 shows the proposed and approved tariff adjustment rates.

**Table 8: Approved multi-year electricity tariff adjustment rates**

	Customer Category	2008	2009	2010	Cumulative increase
Residential	ERB approved	26.8%	16.6%	11.9%	65%
	ZESCO applied	45%	37%	29%	156%
Commercial	ERB approved	1.3%	0.3%	0.3%	2%
	ZESCO applied	50%	10%	10%	82%
Services	ERB approved	6.8%	1.9%	1.9%	11%
	ZESCO applied	49%	22%	21%	120%
Small power	ERB approved	16.2%	5.5%	4.5%	28%
	ZESCO applied	80%	29%	16%	159%
Large power	ERB approved	27.5%	16.6%	2.2%	52%
	ZESCO applied	75%	55%	29%	250%

Source: ERB (2007:32) Energy Regulation Board Decision on ZESCO Limited’s proposal to vary electricity tariffs (Multi Year – 2007/8 - 2009/10)

The approved cumulative tariff adjustment rates are far below the IPA Energy Consulting (2007) recommended adjustment rate of 150 %. The ERB (2007: 22-24) had made the major adjustments to ZESCO’s proposal: the 23 % domestic Loan Interest rate stated by ZESCO was reduced; ERB instructed ZESCO to achieve the staff costs of 40% for 2008, 35% for 2009 and 30 per cent for 2010; ERB rejected the cost of electricity imports from proposed by ZESCO (294MW in 2008, 627MW in 2009 and 823MW in 2010). ERB instructed ZESCO to make realistic estimates because most of the imported electricity was associated with peak times; ERB reduced revenue requirement for ZESCO to K1.2 trillion in 2007/8; K1.7 trillion in 2008/9; and K2.2 trillion in 2009/10, and the effects of the ERB approved tariff adjustment rates on electricity demand across residential, commercial and industry sectors were not quantified by any econometric studies. Therefore, this study is significant because it partly focuses on the response of electricity demand in industries in Zambia to changes in electricity prices or tariffs.

### 4.3 ENERGY EFFICIENCY IN INDUSTRIES

In this section I have presented general literature on energy efficiency in industries and specific literature on energy efficiency in industries in Zambia. Section 3.3.1 has first define energy and energy efficiency, and presented the benefits of energy efficiency to industries; the energy efficiency gap; barriers to energy efficiency in industries; internal measures and actions the industries would consider increasing energy efficiency performance; energy efficiency technologies in industries; and energy efficiency policies. In Section 3.3.2 has presented specific studies on industrial electricity demand in Zambia.

#### 4.3.1 *General literature on energy efficiency in industries*

First, in production theory the term efficiency is twofold: technical efficiency and economic efficiency. Wilkinson (2005) contrasts the two terms as follows:

[Technical efficiency] means that a firm is producing the maximum output from given quantities of inputs. Any production function assumes that a firm is operating at technical efficiency. It follows from this that a given output may be produced in many ways, each one of which may be technically efficient; in other words, that output is the maximum output that can be produced from each different combination of inputs (Wilkinson 2005: 205).

[Economic efficiency] involves producing a given output at least cost. This usually involves a unique combination of inputs, the levels of these inputs depending on their substitutability and complementarity, and also on their prices (Wilkinson 2005: 205).

In this vein, energy efficiency in electricity can be view from both technical and economic perceptive. Generally, energy efficiency simply refers to “the energy services provided per unit of energy input” (Gillingham, Newell and Palmer 2009: 1). However, the World Energy Council explains that energy efficiency has a broader meaning to economists:

...it encompasses all changes that result in decreasing the amount of energy used to produce one unit of economic activity (e.g. the energy used per unit of GDP or value added). In that case, energy efficiency is associated with economic efficiency and includes all kind of technological, behavioural and economic changes that reduce the amount of energy consumed per unit of GDP (World Energy Council 2010: 5).

Second, the neoclassical theory of the firm has been a key framework for many studies on energy efficiency in industries. This theory, according to DeCanio (1993), regards firms as knowledgeable, rational players that steadily maximize profits subject to the constraints

imposed by technology, public policy, and prevailing market conditions. Further, the theory asserts that the technological and financial aspects of a firm are the driving force behind decisions regarding technology adoption, and not firm's characteristics such as relative size, product lines, corporate earnings, and location (Howarth et al. 2000). However, some studies have nullified neoclassical theory of the firm (see, for example, DeCanio and Watkins 1998).

Third, energy efficiency is regarded as a means to achieve overall efficient resource allocation rather than the end in itself. For example, Morvaj and Bukarica (2010) consider energy efficiency as a powerful tool for combating climate change. In addition, several studies have validated the benefits of energy efficiency to industries (see, for example, Baumgartner and Muggli 1996; Blok et al 1996; Howland and Murrow 2009; World Energy Council 2010).

On why the world should be interested in improving energy efficiency, for instance in electricity use, the World Energy Council elaborates that improving energy efficiency will have two benefits: (i) supply more consumers using the same electricity production capacity, which is often the main constraint in many countries of Africa and Asia, and (ii) slow down the electricity demand growth, and reduce the investment required for the growth of the electricity sector; this is particularly significant in countries with high growth of the electricity demand, such as China and many South East Asian countries.

Baumgartner and Muggli (1996) in their study of efficiency improvements of crosscutting technologies in Swiss industry estimated savings of 15–35 per cent for electrical and mechanical drives over the next 10–15 years. Similarly, Blok et al. (1996) projected the economic efficiency improvements for Dutch light industry in 2000 (relative to 1990) at 30 per cent (with a 5 per cent discount rate) and 27 per cent (with a 10 per cent discount rate).

Goto (1996) studied that the energy efficiency improvements through 2010 for several energy-intensive industries in Japan study and found that energy savings for iron and steel ranged from 10 to 12 per cent, for chemicals from five to 10 per cent, for cement production from two to eight per cent, and for pulp and paper from six to 18 per cent.

Howland and Murrow (2009) quantified the macroeconomic impacts of increased energy efficiency investments in New England. They employed a multi-state policy-forecasting model and analysed efficiency programs for electricity, natural gas, and unregulated fuels. They found that the benefits from increased efficiency investments in New England were significant for each fuel type. They go on to predict that increasing efficiency program investments in all six states they studied over 15 years (US\$16.8 billion invested by program administrators) would increase economic activity by US\$162 billion (2008 dollars).

Fourth, in spite of the many benefits of energy efficiency documented in studies, yet there seems to be less investment in energy efficiency by industries than is expected. In short, there is an energy efficiency gap, defined as the “gap” between potential cost-effective energy efficiency measures and measures implemented (York et al., 1978; Stern and Aronsson 1984; Sanstad and Howarth 1994; Sorrell et al. 2000).

Fifth, literature has documented many barriers to energy efficiency. Sorrell et al. (2004) defines a barrier as a postulated means that inhibits investments in technologies that are both energy efficient and economically efficient. Thollander, Palm and Rohdin (2010) have categorized the barriers to energy efficiency as technical system barriers, technological regime barriers and socio-technical regime barriers. Table 9 summarizes the three categories of barriers and supporting references.

**Table 9: Classification of barriers to Energy Efficiency**

Classification	Theoretical barriers	Reference
The technical system	Access to capital	Hirst and Brown (1990)
	Heterogeneity	Jaffe and Stavins (1994)
	Hidden costs	Ostertag, (1999)
	Risk	Hirst and Brown (1990)
The technological regime	Imperfect information	Howarth and Andersson (1993)
	Adverse selection	Sanstad and Howarth (1994)
	Split incentives	Jaffe and Stavins (1994)
	Form of information	Stern and Aronsson (1984)
The socio-technical regime	Credibility and trust	Stern and Aronsson (1984)
	Principal-agent relationship	Jaffe and Stavins (1994)
	Values	Stern (1992)
	Inertia	Stern and Aronsson (1984)
	Bounded rationality	Sanstad and Howarth (1994)
	Power	Sorrell et al. (2000)
	Culture	Sorrell et al. (2000)
<i>Source: Adapted from Thollander, Palm and Rohdin (2010: 59)</i>		

Thollander, Palm and Rohdin (2010:59) go on to argue that re-defining how we should categorize barriers could open up new ways of looking at the problem. They maintain that energy efficiency problems are multifaceted and should be approached accordingly. If a barrier, for example, is known as belonging to a technological regime or a socio-technical regime, it should be approached differently and addressed via individual policy instrument.

Sixth, literature has documented several internal measures and actions that industries can consider in increasing energy efficiency performance (see, for example, Martinez (2009):

energy management systems; energy efficiency investment (for example, changes in machinery, equipment and technology); changes in machinery and equipment; training activities; voluntary audit; major product/process related technological changes, whether or not introduced as part of public/private national and the R&D programmes; optimization of production capacity and production level; conversion of industrial business - in terms of both products and processes.

Seventh, literature documents that activities such as electricity metering, controlling, and optimal regulation can lead to efficiency improvements of up to 15 per cent in most industrial processes (see, for example, Vakulko and Zlobin 1997).

Last, literature has repeatedly documented that effective energy efficiency policies are significant in promoting industry energy efficiency (see, for example, Gillingham et al 2009; Martinez 2009; World Energy Council 2010). Gillingham et al. (2009: 24) maintain that effective energy efficiency policies have two features: they must reduce the barriers to energy efficiency, and they must be cost effective. Martinez (2009) affirms that effective energy efficiency policies in manufacturing industries are those that utilize legal and fiscal instruments to generate supporting framework conditions as well as targeted programs in many fields such as R&D, technological change, market transformation, information, education, and dissemination of best practice.

In this vein, the World Energy Council (2010: 6) explain that the main objective of policy measures is to create the necessary conditions to speed up the development and the deployment of market efficient equipment, through information for and communication with final consumers; economic support through subsidies or tax reduction; deployment of specific financing mechanisms; regulation for appliances, equipment and building, regulation imposing energy savings requirements for consumers and for utilities; R&D and dissemination of expertise in the field of energy efficiency.

Captivatingly, two major criticisms have been levelled against most studies on energy efficiency policies: (i) “free riders” are not always accurately accounted for in econometric assessments (see, for example, Joskow and Marron 1992), and (ii) policy evaluations either ignore or improperly account for the rebound effect, such that energy efficiency improvements decrease the marginal cost of energy services, in so doing increasing demand and stimulating less-than-proportional reductions in energy use (Gillingham et al. 2006).



#### ***4.3.2 Literature on efficient use of electricity in industry sector in Zambia***

As already stated, one of the two aims for this study is to expose any energy efficiency developments or improvements in the industry in Zambia. Energy efficiency improvements, according to the World Energy Council (2010: 4), refer to a reduction in the energy used for a given service (heating, lighting, etc.) or level of activity.

My search for publications on energy efficiency in industries in Zambia was a difficult quest. Plainly, I did not find research publications that specifically address energy efficiency in industries in Zambia. However, the report on “World Energy Assessment Report and the challenge of sustainability” (UNDP 2000) stated that in 28 small and medium size industries in Zambia the energy potential savings are between 15 and 30 per cent.

In addition, the outcomes of the activities by ZESCO and the Government to foster efficient use of electricity in industry in Zambia have not been documented. Sisala (2008), for example, in his presentation on “Challenges and Possible Solutions in the Power Sector in Zambia” exposed that ZESCO had started helping the industry sector in Zambia to implement energy saving measures: installing electric motor optimisers on big motors; using variable speed drives for pulley coupled drives; installing power factor correction equipment (capacitor banks); not starting all industrial machines at the same time to avoid creating local peak loads; arresting all compressed air leaks; insulating all steam pipes correctly; and installing floor mounted capacitor banks.

The Zambian government removed import duty on energy saving equipment and energy generating equipment in 2008 to promote the efficient use of electricity by industries (International Business Development [DIBD] 2011). The removal of import duty is one of several forms of rendering the economic support for the purchase of energy efficient equipment and devices. Other forms, according to (World Energy Council 2010: 6), include loans, subsidies, and tax credits).

Nevertheless, apart from the aforementioned energy saving potential in 28 small and medium size industries in Zambia, no other outcomes of the stated ZESCO and Government efforts in improving efficient use of electricity in the industry sector have been documented or published. Lack of such documentation makes the current study useful in exposing improvements in the efficient use of electricity in the industries in Zambia.

#### **4.4 CHAPTER SUMMARY**

This chapter has reviewed general literature on industrial electricity demand, specific literature on industrial electricity in Zambia, and literature on energy efficiency in industry.

First, the chapter has exposed several pertinent issues on electricity demand in industries: electricity demand elasticity is great in the long run than the short run; electricity demand response to changes in electricity price vary across industries; weather conditions and the time of use of electricity have a substantial impact on electricity demand in industries; potentials for inter-fuel substitution occur; the time trend variable has been used widely in the industrial electricity demand models; and there are mixed research results on whether income elasticities are bigger than price elasticities of industrial electricity demand

Second, studies on industrial electricity demand in Zambia are seemingly insignificant, and the effects of the increases in electricity tariff on electricity demand across residential, commercial and industry sectors were not quantified using econometrics.

Third, although barriers to energy efficiency in industries (categorized as technical system barriers, technological system barriers and socio-technical system barriers) exist and make the energy efficiency gap, yet industries can consider several internal measures and actions to increase the energy efficiency performance. In addition, several studies have placed a premium on effective and appropriate energy efficiency policies for reducing the barriers to energy efficiency industries.

Lastly, ZESCO and the Government of the Republic of Zambia have implemented several efforts for improving the efficient use of electricity in the industry. Nevertheless, the results of such efforts have not been exposed or published.

### 5.1 INTRODUCTION

In the previous chapter I presented the literature review. In this chapter I will present the methodology of the study. I have arranged this chapter as follows: Section 5.2 presents the theory of factor demand; Section 5.3 specifies the econometric model; Section 5.4 describes that data set; and Section 5.5 gives a summary of the chapter.

### 5.2 THEORY OF FACTOR DEMAND

#### 5.2.1 *Theories and laws in economics*

Theories are abstractions that attempt to avoid unnecessary detail in order to expose only the essential elements of observable behaviour (Webster 2003: 5). Theories are formally expressed using models. Models in economics may take the form of diagrams, graphs, or mathematical statements that summarize the relationship between and among two or more variables.

Frequently, more than one theory explains any given economic phenomenon. Therefore, good theories should be chosen over bad ones. Good theories predict with greater accuracy than “bad” theories. Webster (2003: 6) affirms that a theory that predicts an event with greater accuracy must replace alternative theories, no matter how well those theories may have predicted the same event in the past. Understandably, simpler models tend to predict better than more complicated ones (Webster 2003: 6).

Usually, two common errors characterize theories (Webster 2003: 6-7): (i) the fallacy of *post hoc, ergo propter hoc* (literally, “after this, therefore because of this”), and the fallacy of composition (a wrong conclusion that is true for a part is necessarily true for the whole).

Generally, theories differ from laws. The difference is based on their ability to make accurate predictions. Laws inherently predict events with absolute certainty. They are statements of fact about the real world or the relationships that are constant in accordance with specified underlying assumptions. Theories are merely attempts to explain or predict the behavior of objects or events in the real world. Theories cannot predict events with complete accuracy (Webster 2003: 8-9).

Captivatingly, there are very few laws in economics mainly because economics deals with people, whose behavior is not absolutely predictable. One of laws used by the current study is the “law of demand” which I have explained below.

### 5.2.2 The law of demand

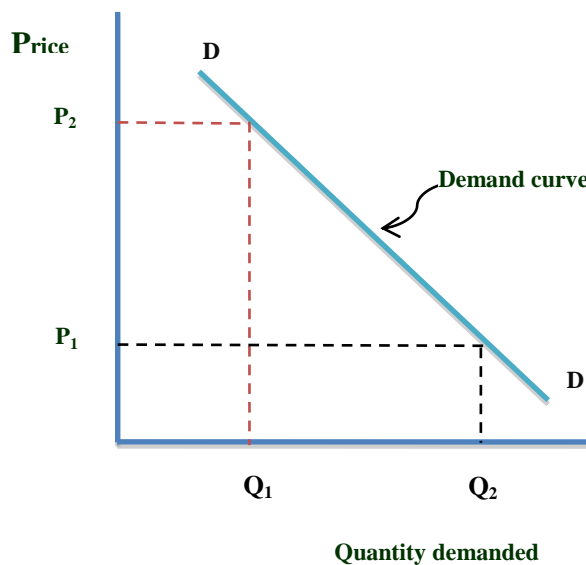
The law of demand states that the quantity demanded of a good or service is inversely related to the selling price, *ceteris paribus* (all other determinants remaining unchanged) (Webster 2003: 100). The usefulness of this law in the current study is theoretically to explain the quantity of electricity demanded when there is a change in the price of electricity. Characteristically, I summarize the law of demand as:

$$Q_D = f(P) \quad (5.1)$$

$$\frac{dQ_D}{dP} < 0 \quad (5.2)$$

Equation (5.1) states that  $Q_D$ , the quantity demanded of a factor or a good, is functionally related to its price  $P$ . Inequality (5.2) asserts that quantity demanded and price are inversely related. This relationship is illustrated by a downward-sloping demand curve shown in Figure 4.

**Figure 4: Demand curve**



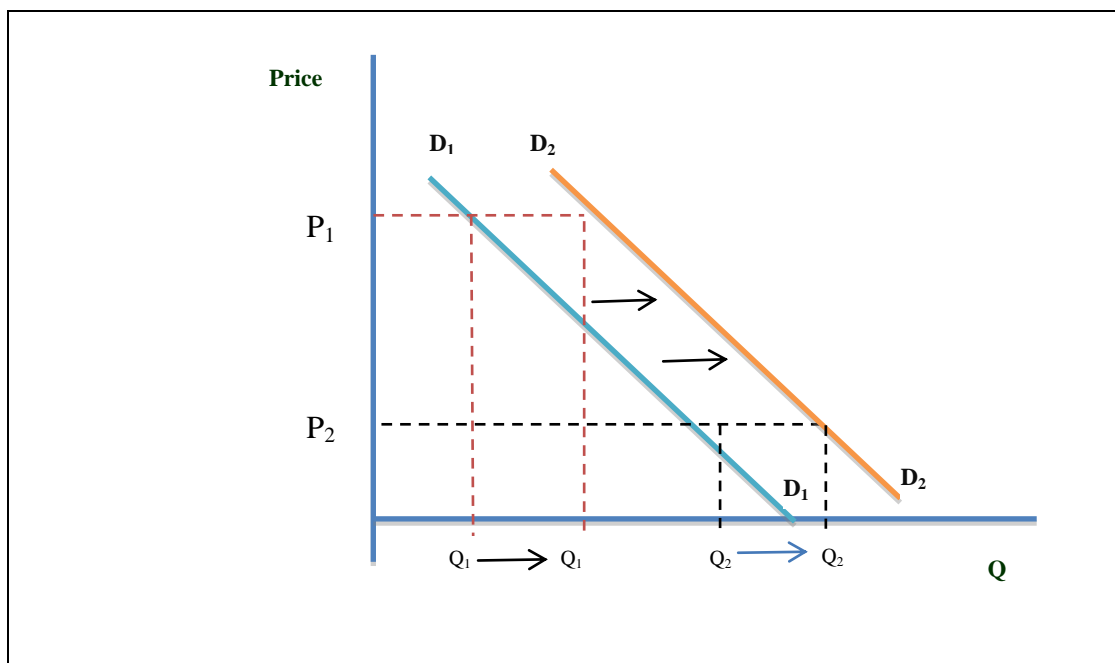
Both the law of demand and the distinction between quantity demanded and demand can be illustrated using tables, graphs and equations. Particularly, tables are not useful for analytical

purposes. Graphs are much more useful than tables for analysis of demand. For instance, the graph in Figure 4 shows the demand relationship as being inverse and linear.

The distinction between quantity demanded and demand is illustrated in Figure 5. The movement along the demand curve, for instance, along  $D_1$ , is called “change in quantity demanded”. The shift of the demand curve (for example, from  $D_1$  to  $D_2$ ) is called “change in demand”, which is caused by the change in one of the determinants of demand other than a change in price. Other determinants include price of a substitute good, price of a complement good, income, and preferences. Some expected directions of shifts in the demand curve are explained as follows:

- If the price of a substitute good drops,  $D_1$  shifts to the left;
- If the price of a complement good drops,  $D_1$  shifts to the right;
- If a firm’s incomes increase,  $D_1$  shifts to the right; and
- If preferences of electricity use change, then  $D_1$  will shift in either direction, depending on how preferences change.

**Figure 5: Shifts in demand curve when income increases**



The major weakness of graphs is that they are limited to examining two-variable relationships contrary to the fact that demand relationships regularly comprise many variables. Equations are the most useful method of illustrating demand for analytical purposes (Wilkinson 2005:76).

Demand equations take many forms: non-mathematical and mathematical forms. The former comprises two-variable and multivariate equations. Equation (5.1), for example, is a two-variable equation. By adding factors like average income of the firm (Y) and the price of the substitute input (Ps), Equation (5.1) becomes a multivariate form:

$$Q = f(P, Y, P_s) \quad (5.3)$$

Mathematical equations have many forms. Wilkinson (2003: 144-145) identifies six forms, which I have adapted and amplified in Table 10.

**Table 10: Mathematical forms of demand equations**

Model	Mathematical form	Transformation	Model's use and limitations
Linear	$Q = a + bP$	$Q = a + bP$	Most frequently used because of its simplicity.
Power	$Q = aP^b$	$\ln Q = a' + b \ln P$	Amenable to regression analysis. Enables the estimation of elasticities.
Exponential	$Q = ae^{bx}$	$\ln Q = a' + bP$	Used mainly to estimate growth rates for time-series data. Is suited for any demand function.
Logarithmic	$Q = a + b \log P$	$Q = a + b \ln P$	Used less often. Suitable for simple regression data.
Inverse or Reciprocal	$Q = a + b \left(\frac{1}{P}\right)$	-	Rarely used model because there are no direct economic interpretation of the coefficients.
Polynomial	$Q = a + b_1 + b_2 P^2 + \dots$	-	Also, rarely used model because there are no direct economic interpretation of the coefficients. Is however useful for modelling cost functions.
<p>Note: <math>a'</math> represents <math>\ln a</math></p> <p>Source: Adapted from Wilkinson (2003: 144 - 146)</p>			

Significantly, the estimation and interpretation of coefficients of the forms in Table 12 matter. The coefficients  $b$  and  $a$  represent the slope of the demand curve and the vertical intercept if the graph is drawn with the  $Q$  variable on the vertical axis. Economically, the value of  $a$  denotes the maximum quantity of a factor or good or service demanded if the price is zero. Practically, this interpretation is limited. On the contrary,  $b$  is of much greater practical importance because it denotes the marginal effect of price on quantity demanded. Implicitly, for every unit the price increases, the quantity of a factor or good or service demanded will rise by  $b$  units. In accordance with the law of demand, value of  $b$  will be negative. Realistically, if this interpretation is extended to multiple-variable equations, such as Equation (5.4), then each coefficient of a variable represents the marginal effect of that variable in quantity demanded.

$$Q = a + bP + cP_s + dP_{t-1} \quad (5.4)$$

where  $b$  represents the marginal effect of  $P$  (current price) on  $Q$ ,  $c$  represents the marginal effect of  $P_s$  (Price of substitute factor for  $Q$ ) on  $Q$ , and  $d$  represents the marginal effect of  $P_{t-1}$  (price of  $Q$  in previous time period) on  $Q$ .

We move away from linear equations and consider the power equations (5) and (6).

$$Q = aP^b \quad (5.5)$$

$$Q = aP^bY^c \quad (5.6)$$

The coefficients  $a$ ,  $b$  and  $c$  denote elasticities. Specifically,  $b$  denotes the price elasticity of demand, and  $c$  denotes the income elasticity of demand. The price elasticity of demand means that for every 1 per cent increase in price ( $P$ ) the quantity demanded ( $Q$ ) will increase by  $b$  per cent. Equally, income elasticity of demand means that for every 1 per cent increase in income ( $Y$ ) the quantity demanded will increase by  $c$  per cent.

Significantly, coefficients of variables in linear equations and those of power equations are not interpreted the same. The coefficients of linear equations are “marginal effects” and those of power equations are “elasticities”. Wilkinson (2005: 79) admits that the interpretation of marginal effects and elasticity as a frequent source of confusion for students. He summarizes the interpretations of the linear and power forms as shown in Figure 6.

**Figure 6: Interpreting coefficients of linear and power forms**

**Linear:**  $Q = a + bP + \dots$

$b$  and other coefficients of variables are marginal effects.

For every 1 unit  $P$  increases  $Q$  increases by  $b$  units ( $b$  is normally negative).

**Power:**  $Q = aP^b + \dots$

$b$  and other coefficients of variables are elasticities.

For every 1 per cent  $P$  increases  $Q$  increases by  $b$  per cent (again  $b$  is negative).

We can also compare and contrast the interpretations of the linear and power forms of the demand equation in the following way:

**Linear** – constant marginal effects, varying elasticities

**Power** – varying marginal effects, constant elasticities

The above information on coefficient interpretation is relevant to the current study. Implicitly, the marginal effects of explanatory variables on the Zambian industrial electricity demand will be treated as varying and their elasticities as constant.

Having introduced and illustrated some aspects of the theory and the law of demand, I will proceed to specify a theoretical model for the study.

### 5.2.1 Theoretical model

Electricity is a major input in the industrial processes in Zambia. The cost theory of the firm entails that each firm in the industry sector in Zambia aims at minimizing the input costs. Bjørner (et al., 2001) explains that if all firms consider the price of electricity and other factors as exogenous and that each firm minimizes its production costs, then demand for electricity can be expressed as a function of the price of the factor inputs and the level of production. In this vein, the problem for mines is the minimization of their production costs in the short term, subject to their production function (technology):

$$\begin{aligned} & \text{Min } P^e e + P^f f + P^o o + FC \\ & \text{subject to} \\ & m = m(e, f, o, \bar{k}), \end{aligned} \tag{5.7}$$

where:

- $e$  is electricity
- $f$  is fuel (diesel or HFO)
- $m$  is the mine's production level of the final compound product,
- $o$  is other inputs that are essential in the production process
- $P^e$  is the price of electricity
- $P^f$  is the price of fuel (diesel or HFO)
- $P^o$  is the price of other inputs, and
- $FC$  is the mine's fixed costs. The stock of capital remains constant (and implies only fixed costs) given the short-term analysis
- $\bar{k}$  is the mine's capital which determines  $FC$ .

Solving problem (5.7), I get the mine's cost function and I can now distinguish between fixed costs (FC) and variable costs (VC):

$$c = c(P^e, P^f, P^o, m, \bar{k}) = FC(\bar{k}) + VC(P^e, P^f, P^o, m) \tag{5.8}$$



I apply Shepard's Lemma and derive the demand function for electricity as:

$$\frac{\partial c(P^e, P^f, P^o, m, \bar{k})}{\partial P^e} = \frac{\partial VC(P^e, P^f, P^o, m)}{\partial P^e} = q(P^e, P^f, P^o, m) \quad (5.9)$$

I suppose that, in the period under consideration, electricity and fuel are separable from other inputs so that the relationships between electricity and fuel with other inputs are neutral in terms of price. Therefore, I can now exclude the price of other inputs from the model. Furthermore, I suppose that the price of the final composite product remains constant and that the electricity demand function depends on the production level. This would be equivalent to functional dependence on the production value.

Having obtained the theoretical demand function for electricity, I will proceed to specify the econometric model and explain the variables included in the model and the reasons for their inclusion.

### 5.3 ECONOMETRIC MODEL SPECIFICATION

#### 5.3.1 *Econometric model*

While there is no agreement in the literature about the most suitable functional form, most of the studies that use individual demand equations adopt a linear or logarithmic form. I choose to use a logarithmic specification, because the estimated coefficients are equivalent to the elasticities and, as such, it is assumed that they are constant. I will use the Ordinary Least Squares (OLS) regression to estimate the function. I assemble the variables in a log linear function as follows:

$$\text{Log\_TEUM} = \alpha_0 + \alpha_1 \text{Log\_AVEP} + \alpha_2 \text{Log\_DPP} + \alpha_3 \text{Log\_IMP} + \mu$$

where:

- *TEUM* is the total industrial electricity used by the mines - the dependent variable;
- $\alpha_0$  is the constant;
- $\alpha_1$  is the own price elasticity,
- $\alpha_2$  is the cross elasticity with respect to the price of diesel or HFO;
- $\alpha_3$  is the total mining index of industrial production elasticity;
- *AVEP* is the average annual price of electricity;
- *DPP* is the diesel pump price;
- *IMP* is the mining industrial of production;

- $\mu$  is the idiosyncratic error term

### **5.3.2 Description of the Variables**

As already indicated in the previous chapter, several researchers have modelled industrial electricity demand using various variables: energy costs, production levels, cross prices, and number of establishments, time trend, time of use, and weather conditions. In the current study I have considered such experience and I restrict the variables to price of electricity, cross price of oil, index of mining production. I have not included dummy variables for the simple reason that logarithms cannot be applied to dummy variables since one cannot take the logarithm of zero.

### **5.3.3 TEUM (total annual industrial electricity used by the mines)**

The total industrial electricity use is the dependent variable. From the literature review and the economic theories already discussed, industrial electricity demand is a function of many variables. However, this study aims at explaining total industrial electricity use in Zambia as a function of  $P_{EL}$  (Price of electricity),  $P_{OIL}$  (Price of oil, in this case diesel), and  $IMP$  (index of mining production). The unit measure of this variable was billion kWh.

#### **5.3.3.1 AVEP (The annual average price of electricity)**

Price of electricity, as stated in the theory of factor demand and the law of demand, is an important variable in the present model. It is expected that when the unit price of electricity is increased, the industry respond by using electricity more efficiently, that is, by implementing electricity conservation and management measures. We expect a negative coefficient on price of electricity indicating that when price of electricity increases by one per cent the quantity of electricity demanded decreases. The unit measure of this variable was the Zambia Kwacha/kWh.

#### **5.3.3.2 DPP (Diesel Pump Price)**

Heavy fuel oil (HFO) and diesel are most accessible substitutes for electricity in Zambia industries, especially in the mining heating and drying processes. Therefore, the current model includes weighted average prices of HFO and diesel with an anticipation that when HFO and diesel prices are increased, most processes within the mining industry will respond by switching to electricity and vice versa. The switch from oil to electricity use should be more

in the long run than in the short run. The unit measure for this variable was the average annual diesel price (Zambian kwacha/litre, or simply the diesel pump price).

#### **5.3.3.3 IMP (*Index of mining production index*)**

Zambia has a wide range of mining products. Thus, it is enormously difficult to use only physical mining products to specify the production level. For this reason, this study uses the monetary value of mine products instead of the number of mine products. Specifically, Index of mining production index is used. It is an index aimed at reflecting the change in the quantum or the physical volume of the output of the industrial sectors of the economy with respect to time. In this vein, it is expected that the total value of final products will have a proportional relationship with electricity consumption in the mining industry. Higher production index would imply greater rates of electricity consumption. Thus the coefficient on industrial production index is expected to be positive indicating that the total electricity demand increases when industrial production index increases by one per cent.

### **5.4 DATA SET DESCRIPTION**

In this section I have summarised and outlined the sources of the data. I used time-series data on the mining industry in Zambia. The industry comprises three sub sectors, namely coal mining, non-ferrous ore mining and stone quarrying.

#### **5.4.1 *Data summaries***

The data on the electricity prices, fuel prices and index of mining production for the period 1980-2008 is summarized in Table 11. The data is presented in the log form.

I have used the Microsoft Excel to obtain the descriptive statistics presented in Table 12. Standard deviation values in Table 12 simply show how much variation or dispersion of the data points from their average mean. The interpretation is that a low standard deviation shows that the data points are very close to the mean, but high standard deviation shows that the data are spread out over a large array of values.

**Table 11: Data on variables**

Year	Log_AVEP	Log_DPP	Log_IMP	Log_TEUM
1980	4,1	1,61	4,85	1,76
1981	2,1	1,61	4,85	1,84
1982	1,3	1,61	4,57	1,82
1983	1,38	1,61	4,46	1,83
1984	1,5	1,61	4,42	1,84
1985	1,61	2,86	4,36	1,85
1986	1,5	2,86	4,01	1,83
1987	1,71	2,86	3,84	1,89
1988	1,71	2,99	3,82	1,9
1989	2,83	3,3	3,82	1,63
1990	2,99	3,36	3,8	1,8
1991	2,99	4,25	3,82	1,79
1992	3,2	4,25	3,89	1,79
1993	3,22	5,46	4,01	1,79
1994	3,47	5,77	4,06	1,78
1995	3,47	6,15	4,13	1,81
1996	3,58	6,59	4,08	1,74
1997	3,64	6,93	4,06	1,87
1998	3,65	7	4,08	1,88
1999	3,79	7,46	4,57	1,78
2000	4,16	8,12	4,61	1,81
2001	3,84	8,08	4,68	1,88
2002	4,16	7,97	4,7	1,96
2003	4,22	8,43	4,83	1,71
2004	4,22	8,39	4,97	2,11
2005	4,32	8,47	5,12	2,15
2006	4,32	8,65	5,2	2,17
2007	4,5	8,87	5,25	2,08
2008	4,5	8,65	5,4	2,03

Source: Author compilation (Used information from various sources)

**Table 12: Descriptive Statistics of the variables**

Description of a statistic	Log_AVEP	Log_DPP	Log_IMP	Log_TEUM
Mean	3,14	5,51	4,41	1,87
Standard Error	0,21	0,50	0,09	0,02
Mode	3,47	5,96	4,39	1,84
Standard Deviation	1,50	1,61	3,82	1,79

### 5.4.2 Data sources

The data sources are summarized in Table 13 and 14.

**Table 13: Sources of data**

Variable	Data source
Industry electricity use	<ul style="list-style-type: none"> <li>US Energy Information Administration DOE (EIA) website. EIA had data on the total annual electricity consumption for Zambia for the period 1986 to 2010.</li> <li>The Directorate of Customer Services Directorate of ZESCO Limited provided me with data on total electricity consumption from 1994 to date 2011. The Directorate indicated that the mining sector consumes an average of 50% of the electricity generated in Zambia.</li> </ul>
Electricity Prices	<ul style="list-style-type: none"> <li>The Zambia Energy Regulation Board (ERB) provided the electricity prices for the period 1980 to 2008. ERB regulates the electricity prices in Zambia. As such, the information on electricity prices is reliable.</li> </ul>
Diesel Pump prices	<ul style="list-style-type: none"> <li>The Zambia Energy Regulation Board (ERB) provided the diesel pump prices for the period 1980 to 2008. ERB regulates the fuel prices in Zambia. So the information on diesel prices is reliable.</li> </ul>
Index of mining Production	<ul style="list-style-type: none"> <li>Zambia Central Statistics Office, under the Ministry of Finance and National Planning. They have a monthly publication called “The Monthly” in which they publish the economic indicators.</li> <li>IMF Staff Country Report No. 99/43 entitled “Zambia: Statistical Appendix”.</li> </ul>
Inflation	<ul style="list-style-type: none"> <li>Zambia Central Statistics Office provided the data on inflation. The data is available in their publication called “The Monthly”.</li> </ul>

Exposing energy efficiency developments in the industries in Zambia is one of the two aims I intended to achieve in this study. Between 5<sup>th</sup> and 28<sup>th</sup> August 2011, I travelled to Zambia and sourced data on energy efficiency from several institutions indicated in Table 14.

**Table 14: Data on energy efficiency developments in industries**

Sources	Type of data collected
<b>National institutions</b>	
Zambia Ministry of Energy and Water Development (MOEWD).	Copies of national policies energy efficiency (EE).
Zambia Ministry of Finance and National Planning (MOFNP).	Copies of both fifth and sixth National Development Plans for Zambia
Zambia Energy Regulation Board (ERB)	Zambia electricity Act of parliament and the Energy Regulation Act.
<b>Suppliers of electricity</b>	
ZESCO Limited	ZESCO energy efficiency policies and strategies aimed at industries

Industrial entities	
Lumwana Mine and Konkola Copper Mines (new mine located in the North-western Province of Zambia).	<ul style="list-style-type: none"> <li>• Mine energy efficiency policies and strategies</li> <li>• Energy efficiency mine structures put in place.</li> <li>• Top management support of energy efficiency efforts.</li> <li>• Documented improvements in electricity use.</li> <li>• Introduction of energy efficiency technologies.</li> <li>• Operational procedures on energy efficiency.</li> <li>• Budget on energy efficiency activities</li> </ul>
Konkola Copper Mines (an old mine located on the Copperbelt Province)	

The data stated in Table 14 and the coefficient of the time trend variable demand function specified above enabled me to identify some of the improvements in efficient use of electricity the mining industry in Zambia.

## 5.5 CHAPTER SUMMARY

This chapter has presented the theory of factor demand, discussed the theoretical model for the study, specified the econometric model and described the data set.

The chapter has illuminated that tables, graphs and equations are all tools for illustrating the law of demand and the distinction between changes in quantity demanded and the change in demand. However, equations are more useful for analytical purposes. Categorically, equations can be either non-mathematical or mathematical. The former comprises two-variable forms and multivariate forms. The latter comprises six categories namely linear, power, exponential, logarithmic, reciprocal, and polynomial. Unlike the other four forms, reciprocal and exponential are rarely used because their coefficients have no direct economic interpretation. Significantly, coefficients of variables in linear equations and those of power equations are interpreted differently. Coefficients of linear equations are marginal effects and those of power equations are elasticities. The gist of this study was to estimate a logarithmic form demand equation.

The chapter has further presented a theoretical model of minimization of production costs by the Zambia mining industry. By applying Shepard's Lemma, a theoretical demand function for electricity has been derived. In addition, an assumption is made that electricity and fuel are separable from other inputs so that the relationships between electricity and fuel with other inputs are neutral in terms of price, thereby making it possible to eliminate the price of other inputs from the model.

Finally, the chapter has specified an econometric model based on the theoretical underpinnings discussed in the chapter. The model aims at estimating the industrial electricity

demand has a function of electricity prices, diesel prices, total mining index of production, inflation, the electricity intense share for the mines, and the time trend. The variables and rationale for including them in the model have been presented. Last, data have been presented, their statistics described and their sources outlined. On this note, the next chapter will present the results of the data analysis.

## 6.1 INTRODUCTION

In this chapter I have presented and discussed the results. Section 6.2 covers the regressions; Section 6.3 presents developments in energy efficiency; and Section 6.4 summarizes the chapter.

## 6.2 REGRESSIONS

### 6.2.1 Results

The independent variables (or predictors) used in the regression were Log\_AVEP (logarithm of average electricity prices), Log\_DPP (logarithm of diesel pump price) and Log\_IMP (logarithm of index of mining production). The dependent variable was Log\_TEUM (logarithm of total electricity used by the mines). To obtain these variables I converted the data to logarithms using the Microsoft excel. The reason for converting the data is to have the coefficients of the regressions as elasticities.

I used the Statistical Package for Social Sciences (SPSS) to run the regression. The regression output is given in Appendix 1. I have summarized the regression results below. The regression is long-run– using data for the period 1980-2008. This is because electricity demand is more elastic in the long run than the short. The long run denotes the period during which all factor inputs are variable.

#### 6.2.1.1 The regression coefficients (elasticities) and model

The coefficients from regression output using enter method, that is when all predictors are entered, are shown Table 15.

**Table 15: Coefficients from regression output using enter method**

Coefficients <sup>a</sup>												
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1 (Constant)	1.209	.170		7.111	.000	.859	1.559					
Log_AVEP	-.060	.034	-.503	-1.785	.086	-.129	.009	.354	-.336	-.248	.243	4.113
Log_DPP	.031	.013	.648	2.340	.028	.004	.059	.497	.424	.325	.251	3.981
Log_IMP	.154	.043	.583	3.593	.001	.066	.242	.641	.584	.499	.732	1.365

a. Dependent Variable: Log\_TEUM



The elasticities or coefficients of interest here are “Unstandardized coefficients”. So the industrial electricity model can be written as follows:

$$\text{Log\_TEUM} = 1.209 - 0.061\text{Log\_AVEP} + 0.031\text{Log\_DPP} + 0.154\text{Log\_IMP} \quad (6.1)$$

Model 6.1 can be interpreted as follows:

#### **Electricity own price elasticity:**

The electricity own price elasticity of demand is -0.06. Interpreting the results of the above model economically, in the long a 1% increase in mining electricity prices, *holding all the other independent variables constant*, reduces the total annual electricity used by the mines by 0.06%. The negative sign on elasticity is the expected sign. The percentage change in prices of electricity induces a much smaller percentage change in total annual electricity used by the mines. Statistically, this predictor is insignificant because its p-value of 0.86 is greater than the pre-selected regression alpha of 0.05.

#### **Cross-price elasticity of demand:**

The cross-price elasticity of demand is 0.031. This signifies that in the long run a 1% rise in diesel pump price, *holding all the other independent variables constant*, induces a 0.031% rise in the total annual electricity used by the mines. The positive sign on the cross-price elasticity indicates that diesel is a potential substitute for electricity in mining. The percentage change in diesel pump price induces a much smaller percentage change in total annual electricity used by the mines. The cross-price elasticity is statistically significant because its p-value of 0.028 is smaller than the pre-selected regression alpha of 0.05.

#### **Index of mining production elasticity:**

The index of mining production elasticity of demand is 0.158. This means that in the long run a 1% rise in the index of mining production, *holding all the other independent variables constant*, induces 0.158% rise in the total annual electricity used by the mines. Compared to electricity own price elasticity and cross-price elasticity, the index of mining production elasticity seems significant. The index of mining production elasticity is statistically significant because its p-value of 0.001 is smaller than the pre-selected regression alpha of 0.05.

### 6.2.1.2 The Success of the model

The coefficient of determination, R Square, measures of the success of our model by shows how much variance of the dependent variable (TEUM in this case) is captured. When the R Square is close to 1, a model can be considered to be very useful for making predictions. The  $R^2$  for regression equation 6.1 is shown in Table 16, with a value of 0.518.

**Table 16: Model Summary**

Model Summary <sup>b</sup>					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.720 <sup>a</sup>	.518	.460	.09545	1.755

a. Predictors: (Constant), Log\_IMP, Log\_DPP, Log\_AVEP

b. Dependent Variable: Log\_TEUM

This  $R^2$  signifies that about 51.8% of the variation in the industrial electricity demand is explained by electricity own price, diesel pump price and index of mining production. The regression equation does not appear to be useful for making predictions since the value of  $R^2$  is not 1. However, we should note that  $R^2$  is a total measure of the strength of friendship, and does not echo the extent to which any particular predictor is associated with the dependent variable.

### 6.2.1.3 How significant is the model?

How significant is our model when we bundle the predictors together? Or, "Do the predictors reliably predict the dependent variable? Our Sig. (0.000<sup>a</sup>), shown in Table 17, which is the p-value associated with the F statistic of (8.953) is very small. Therefore, the model is statistically significant and we can accept the hypothesis that the group of predictors (electricity own price, diesel price and index of mining production) can be used to reliably predict the mining industrial electricity demand.

**Table 17: ANOVA results**

ANOVA <sup>b</sup>						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.245	3	.082	8.953	.000 <sup>a</sup>
	Residual	.228	25	.009		
	Total	.472	28			

a. Predictors: (Constant), Log\_IMP, Log\_DPP, Log\_AVEP

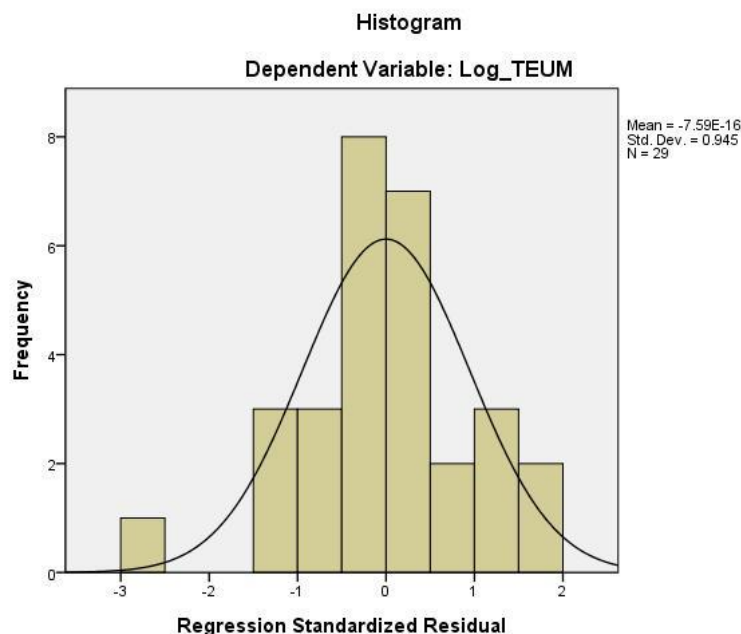
b. Dependent Variable: Log\_TEUM

Nevertheless, this is a complete significance test measuring whether the group of predictors when used collectively reliably predicts the dependent variable. Hence, this does not address the ability of any of the particular predictors to predict the dependent variable. The ability of each individual predictor to predict the dependent variable can be evaluated from the Sig.values in Table 15.

#### ***6.2.1.4 Where there other important predictors not included in the model?***

To test the assumption that all of the important independent variables (predictors) are in our model (or that the residuals are independent and normally distributed, and that they have equal variances for any value of the predictors), we use a normal plot shown in Figure 7. The residuals do not look very normal. Consequently, it is possible that other predictors could explain more variation in the data.

**Figure 7: The Normal Plot - Histogram**



## **6.2.2 Discussion**

The elasticities of all the three predictors (electricity own price, diesel prices and index for mining production) suggested by the theory to influence mining electricity demand in Zambia, the correct signs. However, diesel prices and index for mining production seem to be significant in driving electricity demand by the mines in the long run. I have discussed each of the elasticities below.

### **6.2.2.1 Own price elasticity**

Own price elasticity seem insignificant in driving long run electricity demand for the mines in Zambia. The elasticity of -0.041 is far lower than the average long run elasticity calculated by Dahl (2011), which stands at -0.48. It is also lower than the long run price elasticity of South Africa industrial electricity demand (-0.559 found by Inglesi (2008). It is not even close to the long run elasticity for Turkish industrial electricity demand of -0.16 found by Dilaver and Hunt (2010).

Several explanations can be raised for this lower elasticity. First, the prices of electricity remained very low in Zambia during the period 1980-2008. As already stated, the IPA Energy Consulting (2007) reported those ZESCO under-priced mines and all those companies which who sourced electricity from ZESCO to sell to the mines

Second, GRZ was running both the electricity utility companies and the mines until 1991 when it initiated privatization programme. The government produced and consumed electricity. In such a case, the interest of the government could be the cost of producing and transmitting electricity to the mines.

Third, the exponential increase in prices of minerals like copper during the period 1980-2008 could have offset the seemingly insignificant rise in electricity prices.

Fourth, GRZ made several policy statements that it would keep the prices of electricity as low as possible to attract investment in mining sector. The respondents from Lumwana Mine, Kansanshi Mine and the Chinese-owned mine, Sino Metals, affirmed that GRZ would not suffer to harm the mines by increasing electricity prices.

### **6.2.2.2 Cross price elasticity**

The cross price elasticity showed some statistical significance at alpha 0.05. This long-run indication of cross elasticity is in line with the conclusion by Stein (2010) that the typical

definitions of elasticities of substitution are founded on long-run responses and, consequently, long-run estimates are desirable.

Further, this finding is similar to early studies by Fuss (1977), Deshpande (1966) and Steinberg (1954) which showed little inter-fuel substitution. The finding is also similar to the recent studies and literature by Bölük and Koç (2010), Førsund (2007), and Stein (2010). As already stated, Bölük and Koç (2010) found that substitution possibilities existed between electricity and intermediate input.

The interview with respondents from the mines stated that their mines had several categories of boilers. Some boilers run on diesel and others on electricity. This statement is in line with the observation by Førsund (2007: 10) that in industries boilers can be run on alternative energy sources including electricity and that can be switched from one source to another in a relatively short time.

In additions, the respondents stated that diesel was their alternative energy source, especially for generating electricity. One respondent added that diesel was readily available in Zambia because from Indeni Oil Refinery located on the Copperbelt Province in Zambia.

Although diesel has shown its potential as a substitute for electricity, yet its escalating prices and the strict environmental regulations in Zambia may reduce the substitutability.

### ***6.2.2.3 Index of mining production***

Index of mining production simply measures the volume of production at base year prices for the mining. In Zambia is published on quarterly basis and aimed at measuring changes in the physical production of mining products nationwide. Based on this definition, the elasticity of index of mining production in our regression has the expected sign and is statistically significant. I can partly explain this result using the production function.

First, marginal revenue product and marginal factor cost largely determine the profit-maximizing level of use of electricity by the mines. As long as the marginal the marginal benefits surpass the marginal costs of electricity, the mines may not respond to electricity price increase until the optimal level is reached:

$$MRP_E = MC_E \quad (6.2)$$

where  $MRP_E$  is Marginal Revenue Product of electricity and  $MC_E$  is marginal cost of electricity. As long as  $MRP_E > MC_E$  then more units of electricity will be demanded by the

mines. However, beyond the level  $MRP_E = MC_E$ , any extra unit of electricity consumed becomes a cost to the mine, that is  $MRP_E < MC_E$ .

Second, the role of electricity in mining is vital. I can say “No electricity no copper mining”. Mining in Zambia cannot simply function without electricity. So the volume of production is related to the amount of electricity used.

## **6.3 DEVELOPMENTS IN ENERGY EFFICIENCY**

### **6.3.1 Results**

#### **6.3.1.1 The role played by GRZ**

I accessed GRZ energy efficiency development with regards to national policies and strategies that for energy efficiency in mining industries Policies.

I focused on energy efficiency developments within the context of (i) pricing and tax policies; (ii) for energy efficiency institutional frameworks; (iii) for energy efficiency activities – packages versus single activities; (iv) for energy efficiency private-public partnerships; (v) for energy efficiency regulations (are regulations well planned, regularly strengthened and well enforced?); (vi) GRZ leading by example in for energy efficiency; (vii) promotion of for energy efficiency innovations in Zambia; (viii) GRZ focus on all for energy efficiency potential areas; (ix) Monitoring and Evaluation for energy efficiency; and (x) mainstreaming of energy efficiency in sectoral policies.

#### **Developments in incentive Pricing and tax policies:**

Incentive fiscal and pricing policies are the most efficient way of internalising long-term costs and benefits in the market. In this vein GRZ has been conscious on pricing of electricity in Zambia and has documented that high import duty on for energy efficiency industrial equipment and a progressive increase of electricity prices even at a low rate, broadcasted publicly, can have, in the long-term, a large impact on technological innovation and for energy efficiency.

In this regard, the period under study 1980-2008 witnessed three major developments towards promotions of energy efficiency in mining industry. First, GRZ, through ERB, managed to keep prices of electricity for the mining industry very low. Second, GRZ removed import duty on energy saving equipment and energy generating equipment in 2008. Third, GRZ

through ZESCO and ERB introduced a Time of Use (TOU) tariff. Mines like any other industrial firm could subscribe to the tariff on a voluntary basis. However, GRZ reported that the subscription of mines to TOU had been very low.

### **Developing a favourable and stable energy efficiency institutional framework:**

Here a necessary assumption was that a proper regulatory framework with an energy efficiency law and official quantitative targets for energy efficiency improvement could provide a long lasting context for energy efficiency policies and avoid the negative effect of “stop and start” actions. Did Zambia have such a regulatory framework during the period 1980-2008?

I interviewed one official from ERB and one from MWED and analysed various GRZ documents on energy efficiency institutions in Zambia. Zambia did not have a stand-alone energy efficiency institution. Nevertheless, the Zambian law mandated ERB to monitor electricity utilities for energy efficiency. In addition, there was no legal document stating that ERB should monitor users of electricity such as the mines.

### **Developing the private-public partnerships for energy efficiency:**

Practically, for energy efficiency activities are costly. Therefore, public-private partnerships are a necessary part of public policy on energy efficiency to complement public funds. In this regard, this study aimed at finding out whether GRZ had brought in some incentives (such as soft interest rates, tax credits, etc.) or mandatory targets (like quotas or commitments) during the period 1980-2008. I based this aim on the assumption that Zambia had a stable regulatory environment, which is a necessary condition for involvement of the private sector.

The main incentive for private-public partnership provided by GRZ during the period 1980-2008 was the removal of the import-duty on energy efficiency equipment. Concerning mandatory targets, the environmental licences issued to the mines by the Environmental Council of Zambia, specified the emission limits and the penalties if a violation occurred. The emission limits and penalties implicitly forced the mines to improve on energy efficiency either by acquiring energy efficiency equipment, which are also associated with low gas emissions.

During study interviews I asked the respondent from Lumwana Mine to explain whether Lumwana Mine had partnered with GRZ on energy efficiency. The respondent, illuminated as follows:

“You should understand that Environmental Council of Zambia has given us emission limits for gasses and effluent discharge. So these conditions forces us to install energy efficient equipped. The major advantage we have is that our mine is new and all our equipment are energy efficient...”

### **Developing in for energy efficiency regulations:**

Three activities are deemed necessary in developing for energy efficiency regulations. First, it is prudent for policy makers to give sufficient notice to mines when future for energy efficiency regulations are being planned, so that mines can adapt in advance to future regulations, especially with respect to mandatory efficiency standards. If Zambia introduced for energy efficiency related regulations during 1980-2008, where the mines given sufficient notice?

Second, to remain effective, energy efficiency standards must be regularly updated. So, how regular did Zambia update energy efficiency regulations during the period 1980-2008?

Third, regulations on energy efficiency are effective as long as they are really enforced. To what extent did Zambia enforce energy efficiency related regulations during the period 1980-2008?

The two respondents, one from the Ministry of Water and Energy Development and the other from ERB revealed that policy makers in Zambia gave sufficient notice to the consumers of electricity during the reveal of regulations. The respondent from ERB explained as follows:

“We cannot reveal the regulations without informing the people we regulate. That would be tantamount to professional immorality. In fact, when revealing any piece of regulations here in Zambia, we publish our intentions in national newspapers and through radio and TV programmes. Also, we publish notices in government gazettes”.

On how regular Zambia updated for energy efficiency standards or any for energy efficiency related regulations, there was a general view across the respondents that updating any for energy efficiency related regulations were done only when the need to update them arose”.

### **Zambian public sector leading by example in for energy efficiency:**

How involved was Zambia’s public sector on the promoting a market for energy efficient equipment and services? Did the public sector itself procure and use energy efficient equipment as a proof that the public sector can contribute to promotion and consolidation of a market for energy efficient equipment and services? Was Zambia’s public sector involved at all levels of for energy efficiency related decisions: national, provincial and district.



In response to the above questions, the respondent from the MWED was opinionated that Zambia's public sector could not be a leading example in for energy efficiency that mines could emulate because the public sector did not run mines in Zambia.

There was a general agreement across respondents from the mines that Zambia's public sector did not cherish for energy efficiency in its operations. A respondent from Kansanshi explained as follows:

“If public sector in your questions refers to the Zambian government, then I'm afraid to say that energy efficiency does not exist. Of course we have heard ZESCO advertising on TV about the benefits of saving electricity, but at the same time we are told that ZESCO has not improved efficiency in the transmission of electricity. So to me government is not leading as an example at all...”

### **Promoting for energy efficiency innovations in Zambia's mining sector:**

Had Zambia promoted innovative high impact measures using the experience of the most advanced policies such as efficiency standards for mine operations; energy performance contracting; reduced or credit tax on energy efficient equipment; and energy efficiency obligations?

According to GRZ documents, the period 1980-2008 was characterized with no efficiency standards for mine operations; no energy performance contracting; and no energy efficiency obligations for the mines. However, GRZ had removed import duty on energy efficient equipment but did not put a ban on importation of non-energy efficient equipment.

Did the regulatory bodies such as the Mines Safety Department and the Environmental Council of Zambia promote the efficiency use of electricity in the mines?

In response to the above question, the respondent from MSD just read to the MSD mission to me as follows:

“To formulate, monitor and maintain legislation regarding the safe and sustainable exploration and exploitation of mineral resources and the safe manufacture, transportation, use, storage, destruction, exportation and importation of civil explosives for the maximum benefit for the people of Zambia”.

The respondent further added as follows:

“See, we are a government department, which means we only implement that which the law says we should implement. So “bwana” (Sir), MSD is not legally empowered to regulate energy efficiency in mines”.

The ECZ respondent observed that although ECZ's prime concern with the mines was environment, yet the enforcement of environment laws on mines must have contributed to their acquisition of energy efficient equipment. The respondent had a strong conviction that energy saving equipment emitted little pollutants. The respondent, however, was concerned that the relatively low penalties for violating emission standards, and low electricity tariffs for the mines were strong incentives for some mines to continue using non-energy saving equipment.

### **Addressing all mining activities with energy saving potential:**

A functioning mine comprises several activities that use electricity. This implies that an effective for energy efficiency policy would address all industrial activities with energy saving potentials. Have Zambia's for energy efficiency related policies addressed all energy saving potential activities in the mine?

When asked to explain whether the Zambia's for energy efficiency related policies addressed all energy saving potential activities in the mine, the respondent from the Ministry of Water and Energy Development cautioned as follows:

“As government, we do not have a specific policy on energy efficiency. So what answer do expect from me? I suggest that you ask the mines if they have addressed all the areas where they can save energy”.

The respondent from the ERB indicated ERB had deposited energy saving tips on its website. However, the 6-page document on energy saving tips addressed residential consumers of electricity. Document comprised nine themes: heating/insulation; geyser; lighting; cooking/baking; ironing; refrigeration/fridge; heating; other appliances; and general.

### **Developing Energy Efficiency M&E system for mines**

Many countries were increasingly using energy efficiency indicators to monitor targets of energy efficiency gains. Most governments set quantitative targets required to monitor the progress attained annually.

Did Zambia set quantitative targets required to monitor the for energy efficiency progress in the mines during the period under review, 1980-2008? Had Zambia developed data collection to improve energy efficiency assessments? Were the basic minimum data requirements defined to allow relevant assessment of for energy efficiency in each mine and across mine comparisons? Mines around Zambia could benefit from the exchange of information and experiences on the “best measures” of saving energy.

During the period, under review (1980-2008) Zambia had not set the quantitative targets required to monitor the energy efficiency progress in the mines; not collected data to improve energy efficiency assessments; and not defined basic minimum data requirements for evaluation of energy efficiency in each mine and across mine comparisons.

Specifically, Zambia's National Energy Policy and the Fifth National Development Plan did not mention any quantitative targets required to monitor the energy efficiency progress in the mines. Also, my interviews with ERB and MWED revealed that the government had not set targets for energy saving. In addition, national energy policy and the Fifth National Development Plan had no defined minimum data requirements for energy efficiency evaluation. Furthermore, there was an consensus across the respondents that mines could benefit from exchange of information on EE. However, there were no systematic government efforts to promote energy efficiency information sharing between mines.

### **Mainstreaming energy efficiency in Zambia's sectoral policies**

Here I started with the assumption that: *An integration of energy efficiency policy and other public policies will make the blend of market instruments more efficient.* Therefore, it was economically desirable if all the main sectoral public policies in Zambia had incorporated energy efficiency during the period under review.

In this vein, I analysed two sectoral policies (the Mineral Policy and Strategy for Zambia, and National Policy on Environment) and the Sectoral plans in the Zambia's Fifth National Development Plan, 2006-2010.

I found out that in the Mineral Policy and Strategy for Zambia document, the term energy or electricity never appeared. Similarly, energy issues were not mainstreamed in several Sectoral plans contained in Zambia's Fifth National Development Plan, 2006-2010.

However, the National Policy on Environment (NPE) had mainstreamed energy efficiency. Specifically, its Chapter 9 (The Energy Sector) states the objective of the sector as follows:

“To meet national energy needs with increased efficiency and environmental sustainability”.

Furthermore, NPE states one of its objectives as to “promote energy saving and renewable energy technologies.

#### **6.3.1.2 The role played by electricity utilities**

Was there any need for electricity utilities to concern themselves with the demand side management of electricity in Zambia during the period 1980-2008? The answer is, yes. Yes in the sense that demand-side management refers to actions taken on the customer's side of the meter to change the amount or timing of electricity consumption. Hence, demand side management, according to USA Department of Energy (2007) maximizes end-use efficiency to avoid or postpone the construction of new power generating plants.

Theoretically, I investigated the level of engagement of ZESCO in five activities I deemed necessary to promote energy efficiency in the mines: (i) incentive pricing policies; (ii) Load management programmes, (iii) electricity efficiency rebates, (iv) electricity reduction programmes, and (v) information dissemination of demand side management.

### **Incentive pricing policies:**

The research on “Cost of ZESCO”, conducted by IPA Energy Consulting (2007) reviewed that during the period under review, ZESCO had kept the electricity prices, especially for the mines, very low. As already stated under literature review ZESCO had been under-pricing the mines.

### **Load management programmes:**

Not until 2008, ZESCO changed the electricity load pattern and encouraged less demand at peak times and peak rates. Specifically, ZESCO introduced a Time of Use (TOU) tariff for Maximum Demand consumers, mainly the mines. ZESCO charged all electricity used during the off-peak time period with a discount of a 25% discount on energy charges and a 50% discount on capacity charges. All electricity used during the peak time period attracted a surcharge of 25% penalty on both energy and capacity charges.

ZESCO expected mines to take advantage of the TOU. To the contrary, the TOU tariff was not widely being used. ZESCO emphasized that the TOU tariff was not mandatory for Maximum Demand consumers.

### **Electricity efficiency rebates:**

No electricity rebates were given to the mines for use of energy-efficient products and equipment, which in most cases use far less electricity than their equivalent older models. A respondent from ZESCO explained that during the period under review ZESCO had managed to convince the government to remove import duty on energy efficient equipment.

### **Electricity reduction programmes.**

When asked to state whether ZESCO had introduced any electricity reduction programmes for the mines during 1980-2008, the respondent explained that ZESCO had introduced awareness-raising, training and education programmes. In addition, ZESCO had advocated for efficient lighting in the mines, and helped mines to install electric meters.

According to Sisaala (2008), ZESCO had initiated programmes to enable the mines (i) install electric motor optimisers on big motors, (ii) use variable speed drives for pulley coupled drives, (iii) install power factor correction equipment (capacitor banks) (iv) do not start all your machines at the same time to avoid creating local peak loads, (v) arrest all compressed air leaks, (vi) insulate all steam pipes correctly, (vii) install intelligent motor controllers, and (viii) floor mounted Capacitor Bank to Reduce KVA input and save up to 15% energy

### **Information Dissemination of demand-side management:**

ZESCO conducted awareness campaigns on promoting user benefits and explained no cost/low cost actions. Furthermore, ZESCO marketed energy efficiency programmes by personal contacts with CEO's of the mines in Zambia; and through the media (radio, television and newspapers). The respondent from the mines elaborated as follows:

“We have been proactive disseminating information on energy savings. We know that mines here in Zambia are the biggest consumer of electricity. If the mines use electricity efficiently then ZESCO will have less electrical system emergencies. So our continuous campaign for mines in Zambia to reduce on electricity use is good”.

#### ***6.3.1.3 The role played by the mines***

### **Knowledge about energy efficiency and its benefits:**

During the study interviews, I asked each respondent from the mines to indicate whether the mine top management understood the concept of energy efficiency, its benefits to the mines, and the energy efficiency actions that the mine could take to actualize the benefits.

All the five respondents admitted that the mine top management understood the energy efficiency concept and its benefits. On what energy efficiency actions the mine could take to actualize the benefits, the respondents from Lumwana Mine and Kansanshi Mine emphasized

simply said “energy efficiency policy”. He respondent from Lumwana Mine explained as follows:

“When it comes to our mine operations, policy is very important. If I take you right now round the different sections of the mine, you will realize that we keep to written procedures in all the activities. To me energy efficiency without a written mine policy is a folk story”.

The respondent from Sino metals argued that since the mine’s prime goal is profit maximization or cost reduction, there was need for the mine to be convinced that energy efficiency actions will either reduce the costs or maximize the mine profits. The respondent further explained as follows:

“If energy efficiency could pay in the short-run, every mine in Zambia could be talking about it. But we are told that efficiency will profit the mine in the long run. But how long is the long run? SO for me as long as the government does not entice mines to invest in energy efficiency, then forget it comrade”.

The respondent from Konkola Copper Mines (KCM) explained that although KCM had no written policy on energy efficiency, yet the its upholding of modern mining technology and compliance with Zambia emissions standards had forced the mine engage itself in energy efficiency activities. The respondent elaborated as follows:

“The Environmental Council of Zambia provides us with air permits and other permits. These permits provide emission limits. To meet these limits KCM has been replacing old equipment and with new energy saving equipment. For example, ZESCO helped us install motor optimisers, capacitor banks, and intelligent motor controllers. You should also understand that some buyers of copper abroad inquire as to whether we use environmentally friendly technologies, which to me are associated with low energy intake. I may say much, but we need a long way to go”.

### **Mine energy efficiency policies:**

All the respondents admitted not having come across of a stand-alone energy efficiency mine policy. When asked why no energy efficiency policy, the respondent from Lumwana mine responded with a question: “Mr. Researcher, why doesn’t the Zambian government have a policy on energy efficiency mattered?”

### **Top management support of energy efficiency efforts:**

The general view from the respondents was that mine top management supported those energy efficiency activities imposed on mines by the law enforcers like the Environmental Council of Zambia. In addition, the respondent from Lumwana Mine added that top management had Lumwana Mine had on several occasions considered and approved budgets for training officers in energy efficiency.

### **6.3.2 Discussion**

#### **6.3.2.1 The role played by GRZ**

The results show that GRZ had played a significant role in promoting the efficient use of electricity in the mines in Zambia by removing import duty on energy efficient equipment. This one act is not sufficient to bring about efficient use of electricity by the mines. Besides, apart from new mines (Kansanshi Mine, Lumwana Mine and Kafue Nickel Mine), other old mines were still using old technology associated with energy inefficiency.

The results also indicate that Zambia no national policy on energy efficiency. This renders the role of GRZ in steering energy efficiency in mines as seemingly weak. As already stated in literature review, an effective energy efficiency policy is significant in promoting industry energy efficiency (Gillingham et al 2009; Martinez 2009; World Energy Council 2010).

That GRZ, as a regulator and promoter of energy efficiency in mines, must have a policy is indisputable. Energy efficiency in mines is not a mere one-activity issue but a bundle of activities, whose complexity needs a clear nation policy. In this regard, the World Energy Council (2010: 6) explains that the main objective of policy measures is to create the necessary conditions to speed up the development and the deployment of market efficient equipment, through information for and communication with final consumers; economic support through subsidies or tax reduction; deployment of specific financing mechanisms; regulation for appliances, equipment and building, regulation imposing energy savings requirements for consumers and for utilities; R&D and dissemination of expertise in the field of energy efficiency.

In addition, most of the barriers in energy efficiency faced by the mines could have been addressed by national policies. Gillingham et al. (2009: 24) maintain that effective energy efficiency policies reduce the barriers.

In sum, GRZ could have achieved more developments in energy efficiency in mines during the period 1980-2008 in the presence of an effective national energy efficiency policy.

#### ***6.3.2.2 The role played by electricity utilities***

The results show that electricity utilities like ZESCO had been active in promoting efficient use of electricity helping the mines through incentive pricing policies; load management programmes; electricity reduction programmes; and information dissemination of demand-side management.

The general scenario is that despite all the efforts by ZESCO, the efficient use of electricity in the mines remained relatively low during the period 1980-2008.

First, the reasonable justification for keeping electricity tariffs very low during the period review was to woo investments in mining sector and not to promote energy efficiency. As already stated in literature review (Baxter and Rees 1968; Inglesi 2008; Dilaver and Hunt 2010) electricity demand is price sensitive. Hence, GRZ might have feared that increases in electricity tariffs for mines would have discouraged foreigners to invest in the mining sector in Zambia.

In literature review I stated that a study by IPA Energy Consulting (2007) revealed that ZESCO had been under pricing the mining load, which, at the time of the study, represented 50% of total consumption in Zambia. In addition, ZESCO under-priced contracts for Copperbelt Energy Corporation and new contracts ZESCO was entering into with new retail mining loads. To that effect, IPA Energy Consulting recommended that ZESCO must urgently increase electricity tariffs (by 150 %) and control its costs.

Second, time of use of electricity have a considerable effect on electricity demand in industries (Fan and Hyndman 2010; Cebula and Herder 2010; Hansen 2004). To that effect, ZESCO had introduced TOU electricity. That the mines in Zambia did not make use of TOU tariffs may not be astounding. A respondent from one of the four mines I sampled revealed that electricity costs were negligible compared to the returns:

“I don’t know what is wrong with our government. I participate in the costing of mine inputs. The cost of electricity is not an issue. We just instruct accounts to pay. We are more concerned about transport costs. So wanting us to shift our operations to other times of the day is not profitable at all. So we are comfortable and we do not need TOU this time. May be in future...”



Indeed, ZESCO introduced TOU with good intentions. However, TOU was not a strong incentive during the period 1980-2008. If the changes in profits for adopting TOU were negligible, mines had not would not use TOU. In addition, adopting TOU is based on the assumption that the costs of other mining inputs are constant across all times of the day. However, shifting operations to night times might have increased labour costs through increased wage rate – wage rate at night was higher than the daytime wage rate in most mines in Zambia.

### ***6.3.2.3 The role played by mines***

The results have shown that mines instituted minimal deliberate internal measures and actions to increase their energy efficiency performance. What coerced some mines to make changes in machinery and equipment was the requirement to meet the environmental standards under the Environmental Council of Zambia. The mines could have gone beyond changing machinery and equipment. In her study, Martinez (2009) recommended several internal measures and actions to increase energy efficiency performance: energy management systems; energy efficiency investment; changes in machinery and equipment; training activities; voluntary audit; major product/process related technological changes, whether or not introduced as part of public/private national and the R&D programmes; optimization of production capacity and production level; conversion of industrial business - in terms of both products and processes.

Using Martinez's recommended actions as benchmarks, it is clear that the mines in Zambia did not perform well in energy efficiency during the period under review. The mines had knowledge about the benefits of energy efficiency activities. In fact, all the respondents from the mines agreed that their respective mines knew what energy efficiency was, and that investment in energy efficiency could benefit the mines in the long run. To the contrary, mines were reluctant to implement energy efficiency activities. In short, there was a big "energy efficiency gap", whose definition is already stated in literature review as the "gap" between potential cost-effective energy efficiency measures and measures implemented (York et al., 1978; Stern and Aronsson 1984; Sanstad and Howarth 1994; Sorrell et al. 2000; Schleich and Gruber 2008).

It is cardinal to explain the energy efficiency gap in mines in Zambia within the context of the barriers. From the results it is certain that barriers to energy efficiency in the mines were mixture of three categories of barriers postulated by Thollander et al. (2010): technical system barriers, technological regime barriers and socio-technical regime barriers. Compounding

these barriers was lack of energy efficiency policies (national and mine level) to address the barriers. Thollander et al. (2010) have argued that different regimes of barriers should be approached differently and addressed via individual policy instruments. In general, effective energy efficiency policies are significant in promoting industry energy efficiency (Gillingham et al 2009; Martinez 2009; World Energy Council 2010). To the contrary, both GRZ and the mines had no necessary policy instruments to address the barriers to energy efficiency.

## **6.4 CHAPTER SUMMARY**

This chapter has presented and discussed the results of the regressions and the developments in efficient use of electricity in the mining industry in Zambia.

The predictors used in long run regressions were Log\_AVEP (logarithm of average electricity prices), Log\_DPP (logarithm of diesel pump price) and Log\_IMP (logarithm of index of mining production). The dependent variable was Log\_TEUM (logarithm of total electricity used by the mines). The long run regression results indicate electricity own price elasticity of demand of -0.06; cross-price elasticity of demand of 0.031; and index of mining production elasticity of demand is 0.154. The signs on all three elasticities are as predicted by theory. Whereas, both cross-price elasticity and index of mining production elasticity are found to be statistically significant at pre-selected regression alpha of 0.05, yet electricity own price elasticity is insignificant.

The predicted model has a coefficient of determination of 0.518, which signifies that about 52% of the variation in the industrial electricity demand is explained by electricity own price, diesel pump price and index of mining production. In addition, the p-value associated with the F statistic of is very small, implying that predictors (electricity own price, diesel price and index of mining production) may be used to reliably predict the total annual electricity demanded by the mines.

With regards to developments in efficient use of electricity, GRZ had played a significant role in promoting the efficient use of electricity in the mines in Zambia by removing import duty on energy efficient equipment. However, Zambia had no national policy on energy efficiency to steer energy efficiency in mines and to address the barriers in energy efficiency faced by the mines.

Electricity utilities like ZESCO had been active in promoting efficient use of electricity by helping the mines through incentive pricing policies; load management programmes; electricity reduction programmes; and information dissemination of demand-side

management. Despite all the efforts by ZESCO, the efficient use of electricity in the mines remained relatively low during the period 1980-2008. Even well-intended and targeted programmes, such TOU electricity tariffs, were not adopted by the mines.

During the period under study, the mines instituted minimal deliberate internal measures and actions to increase their energy efficiency performance. What coerced some mines to make changes in machinery and equipment was the requirement to meet the environmental standards under the Environmental Council of Zambia.

## CHAPTER 7      CONCLUSIONS,      IMPLICATIONS      AND RECOMMEDATIONS

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### 7.1 INTRODUCTION

This chapter presents study conclusions, implications and recommendations. Section 7.2 summarizes and concludes salient points emanating from Chapter 6. Section 7.3 presents some of the possible policy and practical implications of this study. Section 7.4 presents study limitations, and finally Section 7.5 presents recommendations.

### 7.2 CONCLUSIONS

#### 7.2.1 *Electricity demand by the mining industry*

##### 7.2.1.1 *Summary of the findings*

The study used three predictors in the long run regression: Log\_AVEP (logarithm of average electricity prices), Log\_DPP (logarithm of diesel pump price) and Log\_IMP (logarithm of index of mining production). The dependent variable was Log\_TEUM (logarithm of total electricity used by the mines). The long run regression results indicate that electricity own price elasticity of demand of -0.06; cross-price elasticity of demand of 0.031; and index of mining production elasticity of demand is 0.154. The signs on all three elasticities are as predicted by theory. Whereas, both cross-price elasticity and index of mining production elasticity are found to be statistically significant at pre-selected regression alpha of 0.05, yet own price elasticity is insignificant.

The predicted model has a coefficient of determination of 0.518, which signifies that about 52% of the variation in the industrial electricity demand is explained by electricity own price, diesel pump price and index of mining production. In addition, the p-value associated with this F (8.953) is very small, an indication that the predictors (electricity own price, diesel price and index of mining production) can be used to reliably predict science the mining industrial electricity demand.

### 7.2.1.2 Conclusions

First, **Hypothesis A** of this study states as follows:

- $H_0$ : *Electricity own-price changes have no significant impact on mining industrial electricity demand.*
- $H_1$ : *Electricity own-price changes have significant impact on mining industrial electricity demand.*

The study assumption was to reject the null hypothesis if a regression result is significant in electricity price variable then. Therefore, in the light of the above summary and the presentations in Chapter 6, I hereby **accept the null hypothesis ( $H_0$ )** and reject the alternative hypothesis ( $H_1$ ). As already explained, the electricity prices for the mines were seemingly very low during the period 1980-2008.

Second, **Hypothesis B** of this study states as follows:

- $H_0$ : *Diesel prices changes have no significant impact on mining industrial electricity demand.*
- $H_1$ : *Diesel prices changes have significant impact on mining industrial electricity demand.*

The study proposition with regards to Hypothesis B is that if a regression result is significant in petroleum price variable then the null hypothesis will be rejected. This will indicate that petroleum price changes have an impact on the industrial electricity demand.

Therefore, based on the above summary and the presentations in Chapter 6, I hereby **reject the null hypothesis ( $H_0$ )** and reject the alternative hypothesis ( $H_1$ ). As already explained, cross price is statistically significant. Its p-value of 0.022 is less than the pre-selected alpha of 0.05.

Third, coefficient of determination of 0.518, entails that **model is useful**. About 52% of the variation in the industrial electricity demand is explained by electricity own price, diesel pump price and index of mining production.

Fourth, the small p-value ( $0.000^a$ ) associated with this F (8.953) makes the **model statistically significant**. The group of predictors (electricity own price, diesel price and index of mining production) can be used to reliably predict the mining industrial electricity demand.

## **7.2.2 Developments in energy efficiency in mining sector**

### **7.2.2.1 Summary of the findings**

The main findings of the study on the developments in energy efficiency in the mining industry during the period 1980-2008 are summarized as follows:

- The GRZ had played a significant role in promoting the efficient use of electricity in the mines in Zambia by (i) removing import duty on energy efficient equipment; (ii) enforcing emissions standards contained in the Environmental Protection and Pollution Control Act of 1990 of the laws of Zambia.
- However, GRZ did not have a no stand-alone national policy on energy efficiency to steer the mining industry towards improvements in energy efficiency.
- The major electricity utility, ZESCO, had been active in promoting efficient use of electricity helping the mines through incentive pricing policies; load management programmes; electricity reduction programmes; and dissemination of information about the demand side management of electricity. ZESCO kept electricity tariffs very low during the period review and introduced TOU tariffs in 2008.
- The mines employed some internal measures and actions to increase their energy efficiency performance. These measures were mainly the changes in machinery and equipment to meet the environmental standards under the Environmental Protection and Pollution control Act of the laws of Zambia. The mines did not implement other measures that are significant in promoting energy efficiency: (i) energy management systems; (ii) energy efficiency investment; (ii) voluntary energy efficiency audits; and (iii) R&D programmes on energy efficiency.
- Like GRZ, the mines did not have stand-alone policies on energy efficiency.

### **7.2.2.2 Conclusions**

Hypothesis C of this study states as follows:

$H_0$ : *There were no developments in energy efficiency in the Zambia mining industry between 1980 and 2008.*

$H_1$ : *There were developments in energy efficiency in the Zambia mining industry between 1980 and 2008.*

In the light of the above summary and the presentations in Chapter 6, I hereby reject the null hypothesis ( $H_0$ ) and accept the alternative hypothesis ( $H_1$ ).

However, I should note that the developments in energy efficiency during the period 1980-2008 minimal compared to the revealed energy saving potential in the mining sector in Zambia. Therefore, had both the government and the mines put in place, implemented, and monitored the policies on energy efficiency, the developments in energy efficiency in the mining industry could have been significant.

### **7.3 POSSIBLE POLICY AND PRACTICAL IMPLICATIONS OF THIS STUDY**

#### ***7.3.1 Implications for the government of Zambia***

The results of this study have twofold implications for GRZ: (i) to policy the demand-side-management of energy (ii) and focus on macroeconomic factors affecting electricity demand for the mines. Regarding the former implication, GRZ should evaluate its effectiveness in promoting energy efficiency in the absence of a national policy on energy efficiency; the role of energy efficiency regulations; consider the implications of the seemingly low import duties on non-energy efficient equipment; reflect on the implication of introduction of a burn on importation of energy inefficient equipment; and consider and quantify the benefits of mainstreaming energy efficiency in sector plans.

In this vein, the findings of this study may help to substantiate the need for GRZ to steer demand-side electricity management.

#### ***7.3.2 Implications for electricity utilities in Zambia***

The study implications for ZESCO are twofold: (i) ZESCO's effects on electricity demand for the mines, and (ii) the role ZESCO can play in promoting energy efficiency.

Based on the aforementioned study findings ZESCO is expected to grasp the impact of its proposed future electricity prices on electricity demand for mines. Equally, ZESCO should consider the economic or econometric implications of under-pricing the mines.

Considering the study findings on energy efficiency it is prudent for ZESCO need to consider several issues: Is there need for a clear policy to define the role of ZESCO should play in promoting energy efficiency in the mines? Has ZESCO been quantifying the energy saving benefits accrued from implemented several activities? Why was TOU programme not fully used by the mines? In which ways can ZESCO partner with other stakeholders in promoting

efficient use of electricity efficiency in mines? Are there other incentives packages of electricity efficiency that ZESCO can consider?

### **7.3.3 *Implications for mining industry***

The study findings have some implications for the mines. First, the mines should understand that electricity demand may not remain inelastic forever, because the suppliers of electricity were determined to make upward adjustments in electricity prices. In addition, the study by IPA Consulting had recommended that ZESCO should stop under-pricing the mines.

Second, the reported developments in efficient use of electricity by the mines were externally driven, mainly by the emission permits from the Environmental Council of Zambia. In this case, mines should have internally driven measures for improving the efficient use of electricity.

## **7.4 STUDY LIMITATIONS**

The first limitation of this study is that the extensive and complex phenomenon of industrial electricity demand has been studied from a rather narrow empirical perspective of using only the mining sector of the Zambia industry. Such a study design limits the generalization of study results.

The second limitation arise from limiting the study to a period 1980-2008, and using only few mines as case studies to uncover developments in energy efficiency in mining industry. Understanding electricity demand from the 1950s, when the first mines in Zambia were established, and including other mines as case studies would no doubt have been fruitful.

The third limitation is that this study focused on the demand side management of electricity, an energy subsector in Zambia that has not been studied. In that case, there was not sufficient reference literature. Therefore, this study has no previous studies on Zambia whose findings could have been validated.

Finally, for additional data collection, I travelled to Zambia on 5<sup>th</sup> August 2011 and conducted interview between 7<sup>th</sup> and 28<sup>th</sup> August 2011. This period was relatively short because of financial constraint, (I was a self sponsored student with seemingly little income). During this short period Zambia was preparing for its tripartite elections that were held in September 2011. For that and other reasons, many mines had their Chief Executive Offices (CEO's) travelled out of Zambia. My aim was to interview mine CEO's to get rich data for the study. I



reduced the number of mines to be interviewed from 7 to 4. Further, having returned to Norway from Zambia, I made follow ups for data clarifications and more using emails and the phone. The responses from these two means of communication had not been prompt. The delays in accessing more data forced me to prolong the completion of the thesis.

## **7.5 RECOMMENDATIONS**

Based on the above conclusions, implications, and limitations, I make the following recommendations for GRZ, Mines and ZESCO (and other electricity utilities) and the future studies.

### ***7.5.1 Government of the Republic of Zambia***

GRZ should consider doing the following:

- Define the role of energy efficiency in national development and have a stand-alone policy on energy efficiency.
- Establish national instruments on energy efficiency. Specifically, EE regulations can be established under Energy Regulation Act.
- Put in place a deliberate policy on integration of EE issues in national sector-based plans. In this way, sectors would identify how their operations are related to and can be influenced by electricity.
- Harmonize national policies in order to maximize the contribution of electricity to economic development.

### ***7.5.2 ZESCO and other electricity utilities***

Electricity utilities should do the following:

- Continue advising mines on efficient use of electricity.
- Introduce rebates on installation of electricity efficient equipment.
- Install electric meters to all mining entities for monitoring

### **7.5.3 Mines**

The mines should do the following:

- Formulate, implement and monitor mine energy efficiency policy that will spell out the mine energy management systems; energy efficiency investment; voluntary energy efficiency audits; and R&D programmes on energy efficiency.
- Develop and support an energy efficiency culture.

### **7.5.4 Future research**

This study has revealed pertinent issues surrounding the mining industrial electricity demand in Zambia and the developments in energy efficiency during the period 1980-2008. My longing therefore is not to paint a picture that this study ends up in the future, but that the future itself must extend this study. To that effect, I recommend that:

- Future econometric studies may use data for entire industrial sector in Zambia, that is data for both mining and manufacturing sectors.
- Whilst this study employed data for the period 1980-2008, future studies may use data dating from 1950s when the mining started in Zambia.
- Whereas the focus of this study was Zambia, and specifically on GRZ, ZESCO and Mines, future studies could extend the focus to include other member countries of the Southern Africa Power Pool.

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## APPENDICES

### APPENDIX 1: SPSS REGRESSION OUTPUT

#### Descriptive Statistics

	Mean	Std. Deviation	N
Log_TEUM	1.8662	.12990	29
Log_AVEP	3.1717	1.08808	29
Log_DPP	5.3714	2.68153	29
Log_IMP	4.4228	.49326	29

#### Correlations

		Log_TEUM	Log_AVEP	Log_DPP	Log_IMP
Pearson Correlation	Log_TEUM	1.000	.354	.497	.641
	Log_AVEP	.354	1.000	.864	.510
	Log_DPP	.497	.864	1.000	.485
	Log_IMP	.641	.510	.485	1.000
Sig. (1-tailed)	Log_TEUM	.	.030	.003	.000
	Log_AVEP	.030	.	.000	.002
	Log_DPP	.003	.000	.	.004
	Log_IMP	.000	.002	.004	.
N	Log_TEUM	29	29	29	29
	Log_AVEP	29	29	29	29
	Log_DPP	29	29	29	29
	Log_IMP	29	29	29	29

#### Variables Entered/Removed<sup>b</sup>

Model	Variables Entered	Variables Removed	Method
1	Log_IMP, Log_DPP, Log_AVEP <sup>a</sup>		Enter

a. All requested variables entered.

b. Dependent Variable: Log\_TEUM

#### Model Summary<sup>b</sup>

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.720 <sup>a</sup>	.518	.460	.09545	1.755

a. Predictors: (Constant), Log\_IMP, Log\_DPP, Log\_AVEP

b. Dependent Variable: Log\_TEUM

### ANOVA<sup>b</sup>

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.245	3	.082	8.953	.000 <sup>a</sup>
	Residual	.228	25	.009		
	Total	.472	28			

a. Predictors: (Constant), Log\_IMP, Log\_DPP, Log\_AVEP

b. Dependent Variable: Log\_TEUM

### Coefficients<sup>a</sup>

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	1.209	.170		7.111	.000	.859	1.559					
	Log_AVEP	-.060	.034	-.503	-1.785	.086	-.129	.009	.354	-.336	-.248	.243	4.113
	Log_DPP	.031	.013	.648	2.340	.028	.004	.059	.497	.424	.325	.251	3.981
	Log_IMP	.154	.043	.583	3.593	.001	.066	.242	.641	.584	.499	.732	1.365

a. Dependent Variable: Log\_TEUM

### Coefficient Correlations<sup>a</sup>

Model			Log_IMP	Log_DPP	Log_AVEP
1	Correlations	Log_IMP	1.000	-.103	-.206
		Log_DPP	-.103	1.000	-.819
		Log_AVEP	-.206	-.819	1.000
	Covariances	Log_IMP	.002	-5.929E-5	.000
		Log_DPP	-5.929E-5	.000	.000
		Log_AVEP	.000	.000	.001

a. Dependent Variable: Log\_TEUM

### Collinearity Diagnostics<sup>a</sup>

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions			
				(Constant)	Log_AVEP	Log_DPP	Log_IMP
1	1	3.844	1.000	.00	.00	.00	.00
	2	.134	5.356	.02	.01	.17	.01
	3	.017	14.997	.02	.97	.80	.01
	4	.005	27.840	.96	.01	.02	.98

a. Dependent Variable: Log\_TEUM

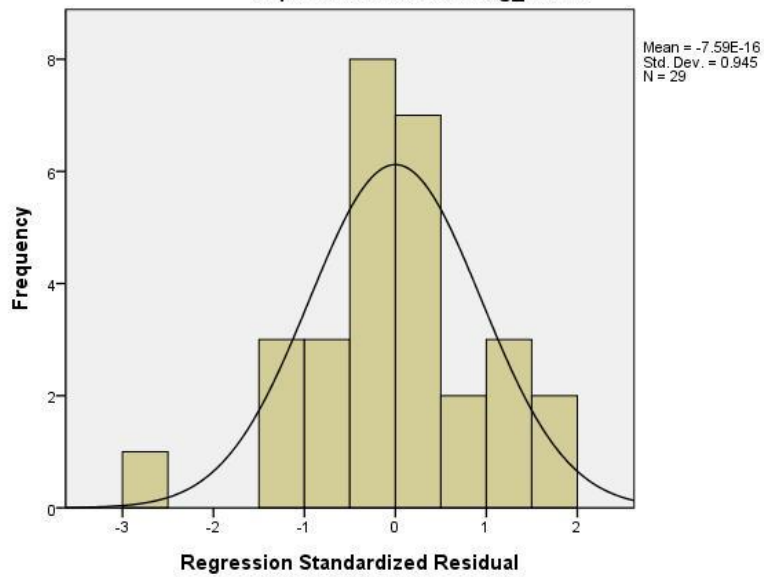
**Residuals Statistics<sup>a</sup>**

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	1.7183	2.0395	1.8662	.09349	29
Residual	-.25188	.15039	.00000	.09019	29
Std. Predicted Value	-1.582	1.854	.000	1.000	29
Std. Residual	-2.639	1.576	.000	.945	29

a. Dependent Variable: Log\_TEUM

**Histogram**

Dependent Variable: Log\_TEUM



**Normal P-P Plot of Regression Standardized Residual**

Dependent Variable: Log\_TEUM

